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Age Composition of the Southern California Catch of Pacific Mackerel 1939–40 Through 1950–51

By
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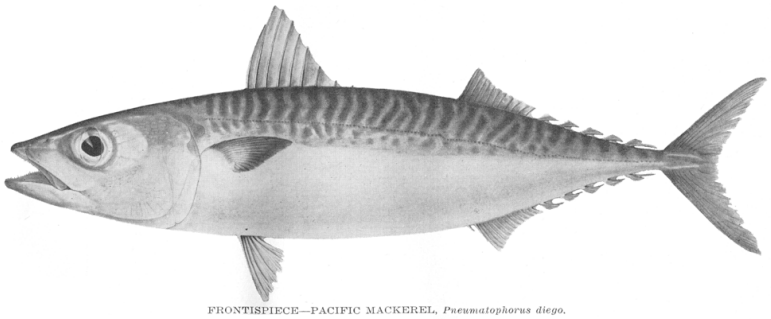

FRONTISPIECE—PACIFIC MACKEREL, *Pneumatophorus diego.*

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ACKNOWLEDGMENTS

The Pacific mackerel age work could not have been accomplished without the wholehearted cooperation of the members of the staff of the Bureau of Marine Fisheries who have done at various times so much of the routine work which is so vital to the success of a program such as this. Particular thanks are due Mr. D. H. Fry, Jr. who instigated the mackerel sampling program, did much of the preliminary age work, made the otolith photographs which have been used in this paper and gave much helpful counsel throughout. Mr. C. R. Clothier has contributed much time and effort in actual sampling of boats, interviewing fishermen, working up month and season summaries and a multitude of other routine and thankless tasks. Mr. Phil M. Roedel offered much advice and encouragement during the preparation of the manuscript. To these and many others go the author's sincere thanks.

JOHN E. FITCH
September, 1951

1. INTRODUCTION

1.1. GENERAL INFORMATION

In July, 1929, the California Division of Fish and Game inaugurated an investigation of the Pacific mackerel, Pneumatophorus diego. From the data obtained it was hoped to be able to formulate policies and recommend regulations which would be most suitable for a sustained mackerel fishery at the highest level possible. A knowledge of the age composition of the catch is of extreme importance in a program such as this.

The biological range of the species extends from the Gulf of Alaska southward into the Gulf of California. Pacific mackerel are not abundant north of Monterey Bay and those occuring south of Central Baja California are probably not important in our commercial fishery (Fry and Roedel, 1949).

1.2. THE MACKEREL FISHERY

Prior to 1928, the Pacific mackerel fishery was conducted almost exclusively for the fresh fish trade. Since that year, with the exception of depression years, 1930–33, the demand for mackerel for canning purposes has been practically unlimited. For many years there was a flourishing early summer fishery; however, this had ceased to exist by 1937 and up to the present writing the fish are available in numbers only during the late summer, fall, and winter months. Although the bulk of the catch is made between July or August, and March, for this report the fishing season is considered to extend from May 1st through April 30th.

The total catch has fluctuated widely from year to year with little relation to economic demand. The greatest landings were made in 1935–36 when 131,000,000 pounds were taken. Since that time, in spite of the increased consumer demands during the war years, there has been a more or less steady decline in landings. The catch in 1950–51 amounted to about 31,000,000 pounds, or less than one-fourth as much as was landed during the peak year.

The present California fishery extends from Monterey Bay south to San Diego, with major landings at the Los Angeles and Orange County ports of Santa Monica, Redondo Beach, San Pedro, Terminal Island, Wilmington, Long Beach, and Newport Beach. Landings at all other ports are of relatively minor importance and have not been included in the age calculation work. Sampling of the catch has been conducted only at Los Angeles and Orange County canneries. The present paper is concerned with the age composition of cannery mackerel landings

in these two counties from the 1941–42 season through the 1945–46 season and with both cannery and market fish for the 1939–40 and 1940–41 and all seasons since 1945–46. Cannery landings make up by far the greatest portion of the entire commercial catch and the landings at Los Angeles and Orange County ports are usually well over 90 percent of the state catch.

1.3. FISHING METHODS AND LOCALITIES

The Southern California mackerel fishery for the canneries was at first prosecuted largely by net boats; first the lampara and later the ring net and purse seine fleet accounted for most of the catch. The net boats in the present fishery are mostly purse seiners which carry crews of 10 to 12 men. All of the net boats capture fish by encircling and then trapping them by either pursing the net (purse seine and ring net) or closing the wings (lampara), forcing the fish into a built-in impounding area or bag. Until the 1939–40 season these net boats landed as much as 90 percent or more of the total cannery catch. Commencing with that season, the scoop and striker fleet has landed the greatest percentage of Pacific mackerel, except for the 1947–48 season when net boat catches surpassed those of the scoop fleet.

Striker fishermen use a bamboo pole which is usually less than eight feet long with three to five feet of line and an artificial lure with a barbless hook. Scoop fishermen use a long-handled dip-net with about a two and one-half foot opening and a bag about three feet deep. In both striker and scoop fishing, mackerel are attracted to the boat by ground up raw fish or "chum" which is thrown into the water. The

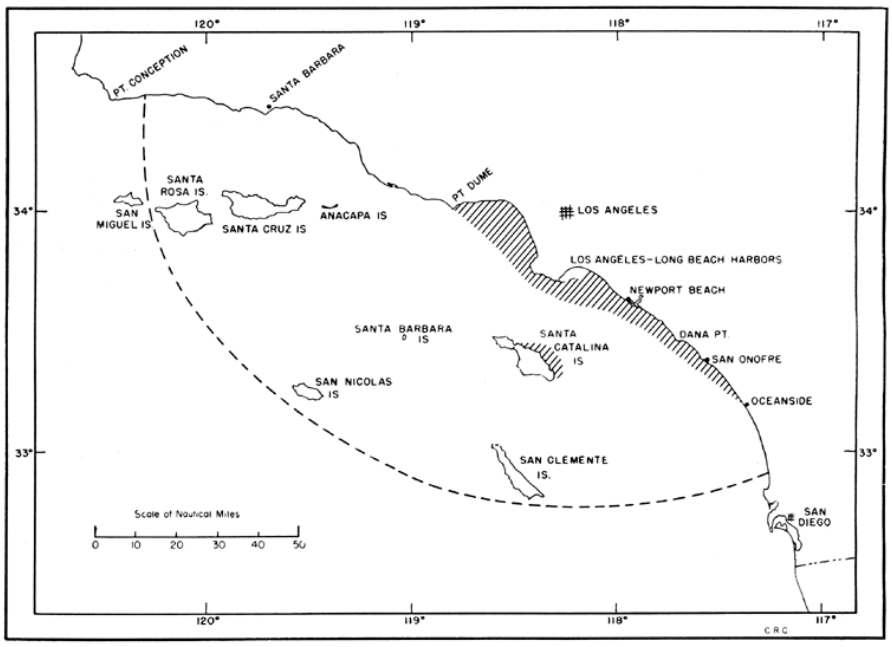

FIGURE 1. The coast of Southern California showing the area fished by the Los Angeles-Newport Beach mackerel fleet. Purse seiners exploit the area inside the broken line. Scoop boats operate chiefly in the shaded area.

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fish thrash about after this food and as many as 30 or 40 can be dipped in one scoopful. At times the fish become quite wary and can only be taken with an artificial lure or striker. Striker fishing began as early as 1928. Croker (1938) gives an excellent account of this fishery and points out that scooping, though in use as early as 1933, was still not the method preferred by these small boat fishermen. Since 1939 strikers have been used only occasionally, but both types of gear are normally carried on the same boat. The only radical change in fishing gear has been from a chicken wire to a twine bag in the scoop net.

The mackerel fleet operating out of Los Angeles Harbor exploits a large portion of the waters off Southern California (Figure 1. The purse seine fleet ranges from near Point Conception in the north to the Del Mar region in the south and offshore to the Channel Islands. The scoop fleet out of Los Angeles Harbor covers Santa Monica Bay, the mainland coast as far south as Newport Beach, and offshore around Santa Catalina Island.

At Newport Beach virtually the entire catch is made by scoop boats fishing along the mainland coast between Huntington Beach and San Onofre and at Santa Catalina Island. At times this fleet will work north to Santa Monica Bay and south to Oceanside.

2. MACKEREL SAMPLING

2.1. HISTORICAL REVIEW

On July 8, 1929, regular sampling of the cannery catch of Pacific mackerel was commenced. This was done only at the Terminal Island canneries until 1931, at which time San Pedro and Wilmington canneries were included. Samples consisting of 200 fish were taken twice a week from all types of boats and gear. In September, 1930, this routine was changed to three times a week with 200 fish each sampling day.

The fish were sexed, measured, and weighed and notes taken as to the condition (maturity) of the gonads. Other information regarding boat name, locality of capture, gear, etc., was also kept. The procedure has changed but little since that date, the greatest difference being in the unit of measurement. An open V-shaped board was used with a metal ruler inlaid at the bottom of the V. This ruler was marked off in one-half centimeter units (millimeters were deemed too small and centimeters too large) and offset in the measuring board one-half unit. This offsetting of the ruler made it possible to place the fish with its snout against a headboard and then read the length to the first line showing beyond the middle rays of the tail fin.

This unit of measurement was changed from one half centimeter to one-fourth centimeter during the summer of 1932.

In September, 1934, it was decided that an unnecessary number of fish were being sampled so the number was reduced to 300 fish once a week (100 from each of three boats). It was also decided at that time that a collection of 100 otoliths would be made each week (50 from each of two boats). Regardless of this decision otoliths were taken only sporadically until December, 1939, when the sampling procedure was again changed. As a result of this change samples of 50 fish were taken

from any boat landing less than 10 tons, and 100 fish from loads of over 10 tons. This was later arbitrarily changed to 50 fish from scoop and striker boats and 100 fish from net boats. Otoliths were taken from 20 percent of these fish sampled, usually either the first or last 10 or 20 fish in the sample.

In November, 1939, deliveries by small boats to the Los Angeles Harbor canneries had become sufficiently numerous to assume fair importance and sampling of these scoop and striker boats was commenced and has continued ever since. Prior to 1939 most of the deliveries by these boats were made at outlying areas such as Santa Monica and Newport Beach and were insignificant compared to the landings by net boats. In September, 1941, sampling at canneries at Newport Beach was commenced. The boats landing fish at these canneries were nearly all scoop and striker boats with a few lampara catches included each month.

In 1941 a review of the otolith sampling procedure indicated that some adjustments were necessary. Too many otoliths from fish in the modal group were being collected and not enough otoliths from fish at the extremes (both large and small). The resulting revised procedure for samples of 50 fish called for the removal of the otoliths of the first fish encountered in each 10 quarter-centimeter grouping (101–110, 111–120, 121–130, etc.). In samples of 100 mackerel, otoliths were taken from the first two fish encountered in each of these 10 quarter-centimeter groupings. If the range of sizes of fish in any particular sample did not yield otoliths from 10 percent of that sample, enough otoliths were removed from fish at the end of the sample to bring the total taken to 10 percent.

This system was found to cover the modal size for any particular age group quite well but left blank spots at the extreme sizes. Since these extreme sizes are of particular importance in determining the change-over from I's to II's, II's to III's, and so on, it became necessary to again adjust the otolith collection procedure. As a result of this change the present system was inaugurated in July, 1948. Under this plan otoliths are removed from the first fish in each five quarter-centimeter grouping (106–110, 111–115, etc.) and no attempt is made to take otoliths from any set percentage of the sample. This system seems to be entirely satisfactory.

2.2. SAMPLING PROCEDURE

The present mackerel sample sheet[1] (Figure 2) first used in 1946 resulted from several refinements of earlier sample data sheets. In recent years in addition to the information called for on this sheet, a notation has been made made giving the amount of ground bait or "chum" used by scoop boat operators in obtaining their load. The information at the head of the sheet concerning the actual catch is obtained from the skipper of the boat at the time the sample is taken. The number of tons landed is the skipper's estimate of the load and is usually quite accurate. This can be checked at a later date against the fish receipt (California Bureau of Marine Fisheries, 1935) which is turned in to the Department of Fish and Game by the canner and which shows the actual poundage landed.

A sampling team usually consists of two individuals; one, the sampler, measures and sexes the fish while the second, the recorder, tallys the

[1] Summing of the individual sample sheets is explained in Appendix A.

Boat Charlie C F. & G. No. F907 Gear seine Sample No. 4275

Tons 35 No. of Men Cannery NKG Date 6 Oct 1951

Locality 4 mi NW W. end Catalina Isl. 29 Males 2930

Time of Sets 11 pm - 1:30 am 21 Females 2165

Tons per Set 5 30 50 Total 5095

Pacific Mackerel Weight of 50 fish 22.3 lbs.

General Area Catalina

cm/4	Male		Female		cm/4	Male		Female	
					121				
					2				
					3				
					4				
75					125				
6					6				
7					7				
8					8				
9					9				
80					130				
1					1				
2					2				
3					3				
4					4				
85					135				
6					6				
7					7				
8			/	⑤ /	8				
9					9				
90					140				
1					1				
2					2				
3					3				
4	/	/	//	③ 2	4				
95	//	2			145				
6	///	3	/	/	6				
7	// ②	2			7				
8	////	4	///	3	8				
9	//	2	/	/	9				
100	/	/	/	/	150				
1	///	3	///	3	1				
2	// ①	2	/	/	2				
3	~~HH~~	5	/	/	3				
4					4				
105			/	/	155				
6	/ ⑦	/			6				
7					7				
8					8				
9					9				
110			/	/	160				
1			/	/	1				
2			/	⑥ /	2				
3					3				
4	/	/			4				
115	/	/			165				
6			/	④ /	6				
7	/	/							
8									
9			//	2					
120									

Sampler R.S.C. Recorder D.H.F.

FIGURE 2. Hypothetical sample sheet. The encircled numbers to the right of the frequencies at 88, 94, 97, etc., quarter-centimeters correspond to the number on the otolith envelope. Figures which are entered to the left and right of "males" and "females" in the upper right are sums of fish sampled and sums of their lengths. "Time of sets" and "tons per set" are used only for net boats.

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information. After many trials the following method for otolith collection was found to be the most satisfactory. When the sampler encounters a fish from which otoliths are to be removed he places the fish on its left side on a cutting board. A slice with a sharp knife is made through the head from side to side (Figure 3). This cut if made on a line from the back of the head through the postero-ventral border of the eye and just forward of the posterior edge of the maxillary will expose the brain

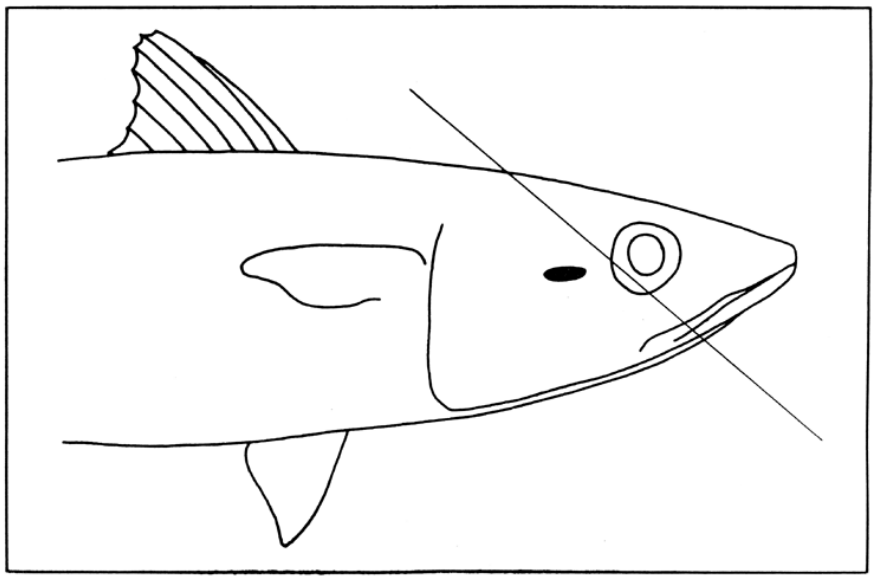

FIGURE 3. The diagonal line indicates the cut which is made to remove the otoliths, the approximate position of which is indicated by the blackened area

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capsule. The brain is scooped out with the blunt end of a pair of finely pointed forceps. The otoliths are then lifted out of their cavities in the floor of the skull with the forceps and placed on the back of the sampler's wrist. The enveloping sacs are removed by manipulation of the forceps and the exposed sagittae are then wiped clean by rubbing gently with a finger. This cleaning of the otoliths is very important if any accuracy is desired in future readings. The pair is then dropped into a small coin envelope on which has been noted by the recorder the sample number, date, and otolith number. This otolith number is also recorded on the sample sheet opposite the tally for that particular fish. This is necessary in order to determine the length and sex of the fish at a future date. Length is not recorded on the envelope so that the reader will not be influenced at the time the otoliths are read.

Otoliths are numbered serially for each sample in the order in which they are removed. When a sample is completed the envelopes for that particular sample are bound with a rubber band. These are later stored serially in boxes by sample number and can be read whenever desired.

3. AGE OF FISHES

3.1. INTRODUCTION

Many different methods of age determination have been proven satisfactory for different fish. For any given species, however, it is necessary by trying several methods to determine the one which best suits the species concerned. Determining age from examination of body structure depends upon the presence of zones of modified appearance which are brought about by seasonal changes. If these seasonal changes can be shown to occur in cyclic series but only once each year the pattern is an annulus. It is necessary to determine the time of formation of this annulus separately for different structures within a species as well as for different species (Menon, 1950; Yasuda, 1940).

3.2. HISTORICAL REVIEW

It is extremely difficult to determine exactly who is the first worker responsible for age determination as applied to fisheries work. Morrow (1951) states that the length-frequency method was originated by G. O. Sars in the 1860's and 1870's and was fully developed by Peterson (1895).

Hoffbauer (1898) seems to have pioneered the use of scales in age determination in his work on carp. Since Hoffbauer's work, the validity of this method has been thoroughly demonstrated by Creaser (1926), Hile (1931), Beckman (1943) and many others.

The use of otoliths, vertebrae, opercular bones, and the pectoral girdle as age determinants closely followed the work of Hoffbauer with the scale. Reibisch (1899), Jenkins (1902), Heincke (1904) and Maier (1906) all investigated different phases of one or more of these structures. Even more recently, such bones as the pectoral rays, dorsal spines, cleithrum, supraoccipital crest, and other skull bones have been successfully aged. Menon (1950) presents an excellent review of many of the more important researches along these lines.

Among the structures customarily used for age determination, the otoliths are the only ones suitable for this study of Pacific mackerel (reasons for this will be discussed later in the paper). The present discussion will therefore largely be confined to a consideration of otoliths.

3.3. OTOLITHS

3.3.1. General Information

According to Adams (1940) the knowledge of otoliths goes back at least to the time of Aristotle. Ancients knew them as stones in the heads of fishes, colic stones, and lucky stones and considered them valuable in treating certain diseases. Adams further states that the term "otolith" did not appear in zoological literature until the middle of the nineteenth century.

At present the three pairs of bones which make up the inner ear of fishes are known as lapillus, sagitta, and asteriscus. These bones are found enclosed in membraneous sacs known respectively as utriculus, sacculus, and lagena. Only the sagitta (largest), which is contained in the sacculus, is used in age determination of Pacific mackerel.

In Pneumatophorus sagitta and asteriscus are located in their respective sacs in deep pits in the floor of the skull. Lapillus is found in the utriculus along the lateral walls of the brain case.

The otoliths appear early and can be seen in X-ray photos of fish embryos as soon as the ear is formed. Because of their structure they offer material of value in several types of fish study besides age and growth: i.e., ancient fish fauna (Frost, 1928); food of other vertebrates (Scott, 1906; Adams, 1940, and Vladykov, 1946); classification and phylogeny (Sanz-Echeverria, 1949, and Marticorena, 1936).

3.3.2. Function

Parker (1910) performed some experimental work on the Atlantic weakfish (Cynoscion regalis) in an attempt to determine the function of the various parts of the internal ear. He states that three chief functions generally ascribed to the vertebrate ear are: hearing, bodily equilibrium and tonus of skeletal muscles. In his experiments he found that weakfish whose eyes were covered with blinders usually swam with normal equilibrium. When the utriculi and semicircular canals were destroyed they were temporarily unbalanced, but recovery to normal equilibrium was rapid. If, however, in addition to destroying these parts of the inner ear the eyes were covered with blinders, these fish swam with great irregularity and had all appearances of having lost their equilibrium entirely. These same fish showed marked muscular weakness but responded to sounds as did normal individuals.

Those specimens which had their sagittae pinned down retained normal equilibrium and showed no diminution of muscular strength, but they responded to sound only to a slight degree.

From these experiments Parker concluded that the utricular organ has to do with equilibrium and muscular tonus and the saccular organ plays an essential part in hearing.

3.3.3. Structure and Composition of Sagitta

Most workers agree that the sagitta is secreted by its enveloping sacculus and is made up of an organic fibrous network and radiating layers of inorganic calcium carbonate crystals. Immerman (1908) made a detailed study of the otolith of a European flatfish and contributed much of our present knowledge. Hickling (1931) reported on the structure of the otolith of a hake and concurred with most of Immerman's findings. Hickling's work seems the more reliable of the two in several respects. He interpreted the white summer rings of the otolith as being caused by the greater thickness of organic lamellae laid down during the summer. This contradicted Immerman's theory that the opacity of this zone was caused by a bending of the calcium carbonate crystals.

In an attempt to clarify this situation, several different analyses were performed on sagittae of mackerel by the author during 1951. In quantitative tests about 90 to 95 percent of the weight of the otolith was calcium carbonate (calcium oxide and carbon dioxide). Very slight traces of magnesium and phosphate were also found, but were in quantities considerably less than 1 percent.

FIGURE 4. Pacific mackerel otoliths (sagittae) age groups O, I and II. Photographs by D. H. Fry, Jr.

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The weight of organic material present was determined by first completely dissolving the calcium carbonate in acetic acid, which was then drained off. The remaining organic matrix which retained somewhat the shape of the original otolith was then thoroughly dried and weighed. The weights of several different trials varied from about 4 to 8 percent, with an average weight of slightly over 6 percent of the total otolith weight. No tests were made to determine physical makeup of this organic material, but it is assumed to be collagen fibers.

Examination of thin sections under high magnification reveal the calcium carbonate to be crystalline in nature with the crystals laid down radially. Organic fibers cut the axes of these crystals at irregular intervals. In the summer zones, where the organic fibers are extremely numerous, the planes of these calcium carbonate crystals appear to diverge in several directions possibly accounting for some of the opacity of these zones. An X-ray spectroscopic examination did not indicate that there was any bending of individual crystals. By boiling crushed otoliths in a cobalt-nitrate solution it was determined that these crystals are aragonite and not calcite. Similarly, Dannevig (1933) found the cod otolith to be aragonite. The zones used in age determination are due almost entirely to a differential content of organic matter. During the summer, a period of rapid growth in the mackerel, calcium carbonate, which is added around the entire otolith, but particularly on the anterior and posterior ends, is heavily impregnated with organic matter. In the winter when growth is slower, the crystals appear slightly larger and the zone contains infinitely less organic matter. As a result the summer zone has a white appearance and is opaque in reflected light, while the winter zone appears clear and transparent.

That growth or metabolism is an important factor in otolith formation is seemingly substantiated by the work of Rollefsen (1933, 1934, 1935). He found with the cod otolith that not only could he determine the age of the cod but he could also determine at what age any particular individual had first spawned. He demonstrated that this shows on the otolith as a summer zone which is only about half the width of the previous summer zone and from there outward to the margin of the otolith the summer zones continue as very thin bands. This narrowing down of the summer zones after 6 to 15 years (average 10 or 11) he defines as the age at which the cod first spawns. He states that this phenomenon could be due to any or all of several factors including: "inception of sexual maturity, the ripening of the gonads, the spawning, the fast during spawning, the spawning migration and the stay in a new habitat, ..."

This same narrowing down of summer zones on the otoliths is also typical of the Pacific mackerel (Figures 5 and 6), the first such ring usually appearing the third or fourth summer, an age at which these fish are known to spawn for the first time (Fry, 1936b). Mackerel two and three years of age are 12 to 14 inches long and weigh between three-fourths of a pound and a pound.

FIGURE 5. Pacific mackerel otoliths (sagittae) age groups III, IV and V. Photographs by D. H. Fry, Jr.

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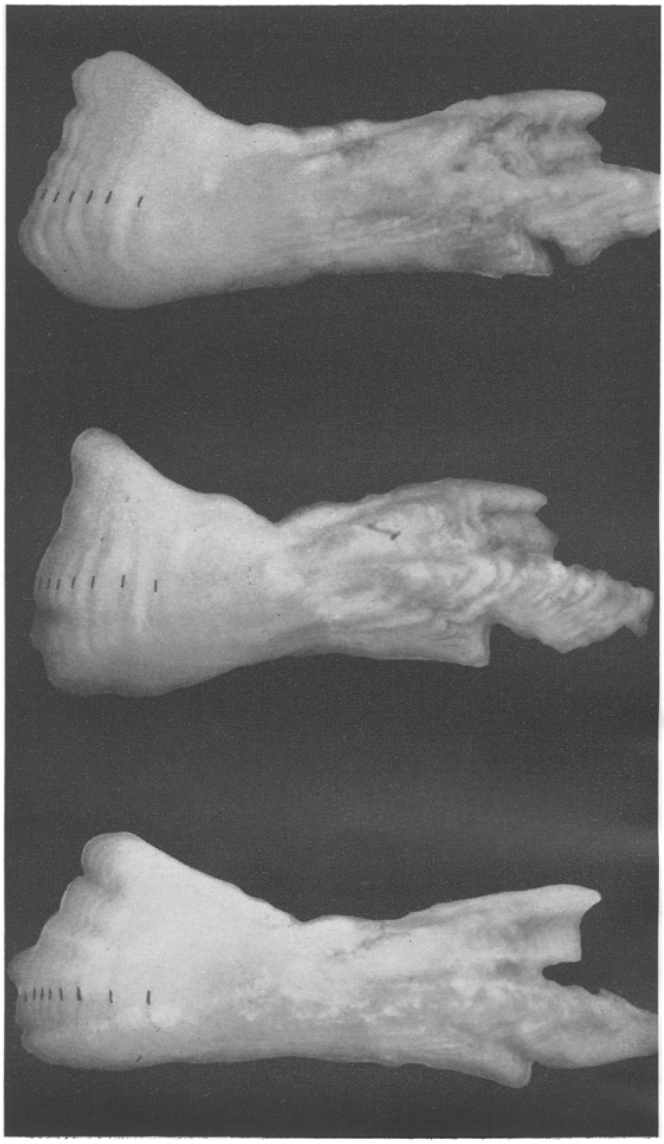

FIGURE 6. Pacific mackerel otoliths (sagittae) age groups VI, VII, and VIII. Photographs by D. H. Fry, Jr.

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4. AGE DETERMINATION OF PACIFIC MACKEREL

4.1. INTRODUCTION

As stated earlier it has been necessary to use otoliths in age determination studies of the Pacific mackerel. The scales, being deciduous, are almost completely lacking at the time the fish are delivered to the canneries where sampling is carried on. For this reason it has been impossible to use scales. Otoliths are more easily removed than other bones of the head and skull and storage of numbers of otoliths does not require a great deal of space. Removal of vertebral sections would mutilate the fish to such an extent that it would no longer be of value for canning purposes; with otoliths this undesirable feature does not exist.

4.2. RELIABILITY OF MARKS ON MACKEREL OTOLITHS FOR AGE DETERMINATION

Prior to acceptance without reservation of any method of age determination it is necessary to prove beyond any reasonable doubt that the differentiated zones which appear on the particular structure to be used are annual in their formation. With the Pacific mackerel several approaches to this problem have presented themselves, and all have been thoroughly investigated. of primary concern was the necessity to determine the appearance and extent of the nucleus or first six-months growth zone. Through several seasons numbers of small mackerel of the year were collected periodically from the time of their first appearance in July until a full year's time had elapsed (Figure 7). Pacific mackerel are known to spawn in Southern California waters from the last of April through part of August (Fry 1936b). Small mackerel of the year usually can be first found in the shallow, inshore area between San Pedro and Newport Beach. Some of these fish were taken in commercial bait hauls with lampara nets, others were dipped from under a light to which they had been attracted at night, but the bulk were caught by hook and line fishing from one of the piers along our coast. Otoliths were removed from all of these, their size and shape, plus the nature of their margins, were tabulated.

All of the otoliths of the 100 mackerel collected on July 1 (Figure 7) were completely opaque and at this time the fish averaged 69.5 quarter centimeters fork length.[1] Two of the 100 otoliths examined August 29 showed translucent margins, the remaining 98 were completely opaque. On November 17 when the fish averaged 79.6 quarter centimeters, somewhat more than half of the 600 otoliths had translucent zones at their margins. By March 22 several of 100 otoliths had complete winter zones outside the opaque nucleus and the margins of these showed the beginning of a second opaque zone. All of the remainder had only an opaque center and a translucent margin at this time. Finally, on July 30 nearly all of 500 fish, whose average length was 104.4 quarter centimeters had well developed opaque margins on their otoliths indicating that the

[1] Quarter centimeters may be converted into millimeters by multiplying times 2.5 or into centimeters by dividing by four since one quarter centimeter is 2½ millimeters or one-quarter of a centimeter.

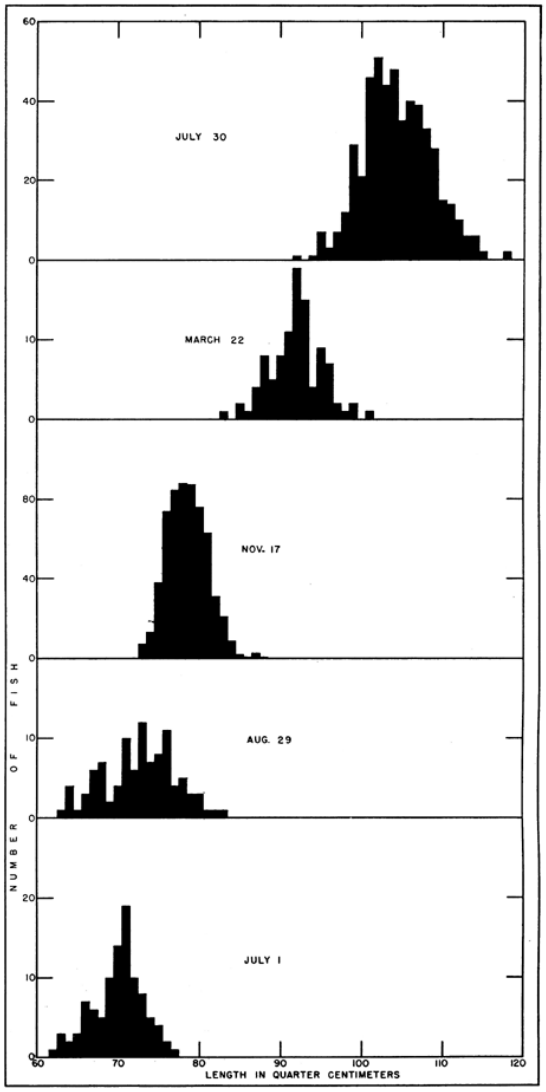

FIGURE 7. Lengths of small mackerel from the time of first appearance July 1, 1947, until July 30, 1948. Numbers of fish were 100, 100, 600, 100 and 500, respectively.

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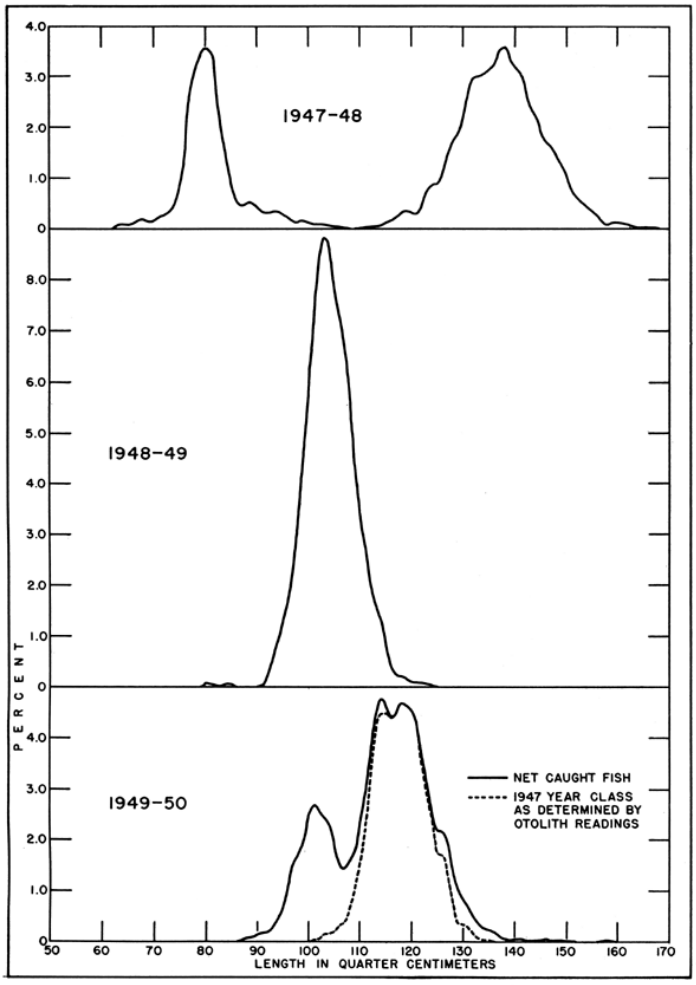

FIGURE 8. Length frequencies of net-caught mackerel sampled during the seasons 1947-48 to 1949-50, inclusive. Figures show percentage at each length of the total fish sampled during the particular fishing season.

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alternate opaque and translucent zones appearing on the otoliths of Pacific mackerel are annual in their formation.

Larger fish were also caught and from these, both scales and otoliths were removed at the time of their capture. The number of winter marks appearing on the otoliths were checked against the annuli on the scales. The marks on both of these were always in close agreement.

A final proof of the validity of the otolith method of age determination of Pacific mackerel presented itself with the entrance into the fishery during the winter of 1947–48 of the extremely good 1947 year class. These fish were so numerous that it was a simple matter to follow them through the two succeeding years and to check the otoliths against not only the scales but the length frequencies (Figure 8).

In Figure 8 percentage frequencies of net-caught mackerel have been plotted for seasons 1947–48 through 1949–50. The percentage of the 1947 yet class (determined from otolith readings) at each length was compared to these frequencies. For the 1947–48 season the 1947 year class percentage curve is so nearly identical to the net-caught fish curve which lies between 62 and 107 quarter centimeters that it cannot be separated from it. The same holds true for the 1948–49 season for the curve between 91 and 122 quarter centimeters. For the 1949–50 season

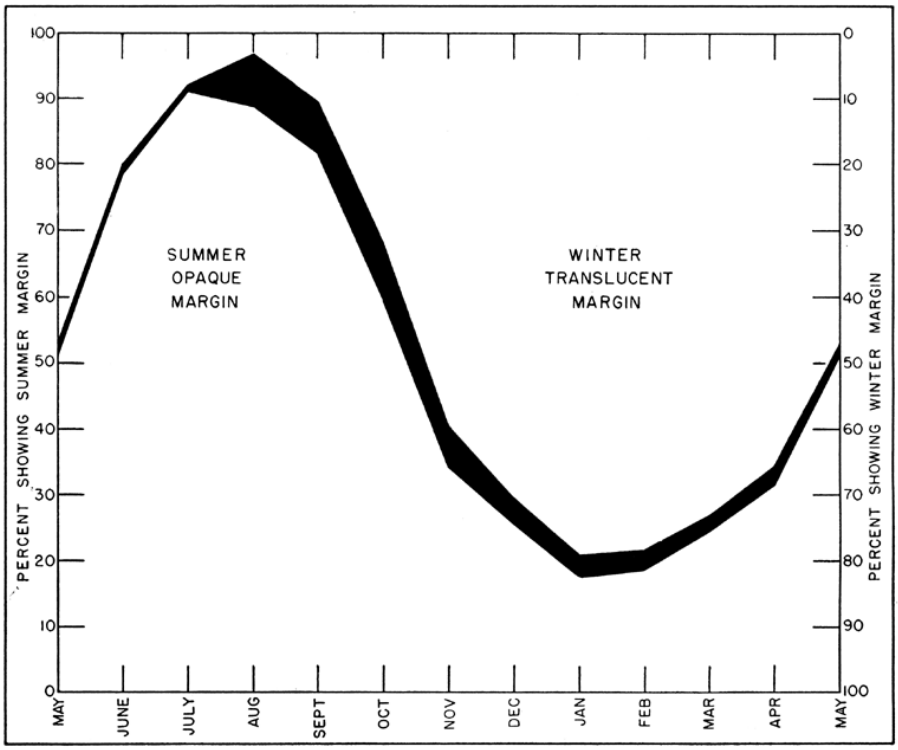

FIGURE 9. Percentage of otoliths showing summer and winter margins for each month of the year. Heavily shaded area represents percentage of otoliths for which character of margin could not be determined. Numbers of otoliths upon which this figure is based are 120, 173, 217, 700, 412, 452, 544, 510, 406, 557, 283 and 188, May through April respectively.

FIGURE 9. Percentage of otoliths showing summer and winter margins for each month of the year. Heavily shaded area represents percentage of otoliths for which character of margin could not be determined. Numbers of otoliths upon which this figure is based are 120, 173, 217, 700, 412, 452, 544, 510, 406, 557, 283 and 188, May through April respectively

nearly 12 percent of the fish 105 quarter centimeters long were of the 1947 year class while over 64 and 97 percent of those at 110 and 115 quarter centimeters respectively were of the 1947 year class.

Figure 9 illustrates the changes in character of the margin of the otolith as determined from over 4,500 pairs. From this figure it may be seen that the margin of the otolith is rapidly changing from translucent to opaque between April and June. By July over 90 percent of all otoliths have an opaque margin. Between September and November the percentage showing a definite translucent edge changes from 11 to nearly 60, and by January a maximum of nearly 80 percent have an outer winter zone. The relatively high percentage of otoliths which show an opaque margin during the winter months is probably due to the fact that the Pacific mackerel live in an ocean environment of moderate temperature. Seldom does the minimum temperature in which these fish are found go below 50 degrees F.

4.3. MATERIALS AND METHODS

For reading, the pair of otoliths is removed from the envelope in which it had been stored and immersed in about a quarter inch of water contained in a flat dish and the dish placed under a binocular microscope. Other fluids and media have been used by various workers (Morrow, 1950; Johnston, 1938); however, water has proved entirely satisfactory for examination and reading of Pacific mackerel otoliths. If left submerged in water for too great a period of time they become saturated and transparent throughout, rendering them temporarily unreadable. Drying quickly restores them to their original condition, clean and easy to handle.

A beam of light from a small microscope lamp or some other light projector is directed at a low angle onto the otoliths. The most suitable angle to show the growth rings to best advantage is found by adjustment of the light. Once this angle has been determined, no further adjustments are necessary. Shading with the finger by moving it upward into the beam of light midway between projector and otoliths improves readability immensely. With a magnification of 25 to 30 diameters the rings on the individual otolith are easily distinguished and the translucent (winter) bands are counted and recorded.

In order to keep all age data comparable it is necessary to set a date by which time both the summer and winter rings can be considered completed. The greatest change from a translucent to an opaque margin takes place in the mackerel otolith between April and June. Since over 50 percent of the otoliths examined in May showed a distinct summer ring at their margin (Figure 9), and since the mackerel fishing season has ordinarily terminated by that date, any fish taken after April 30 is considered to have a completed winter ring on the margin of the otolith. The most rapid change from an opaque to a translucent margin takes place some six months later, between September and November; consequently, September 30 was selected as the date after which all otoliths would be considered as having a completed summer ring.

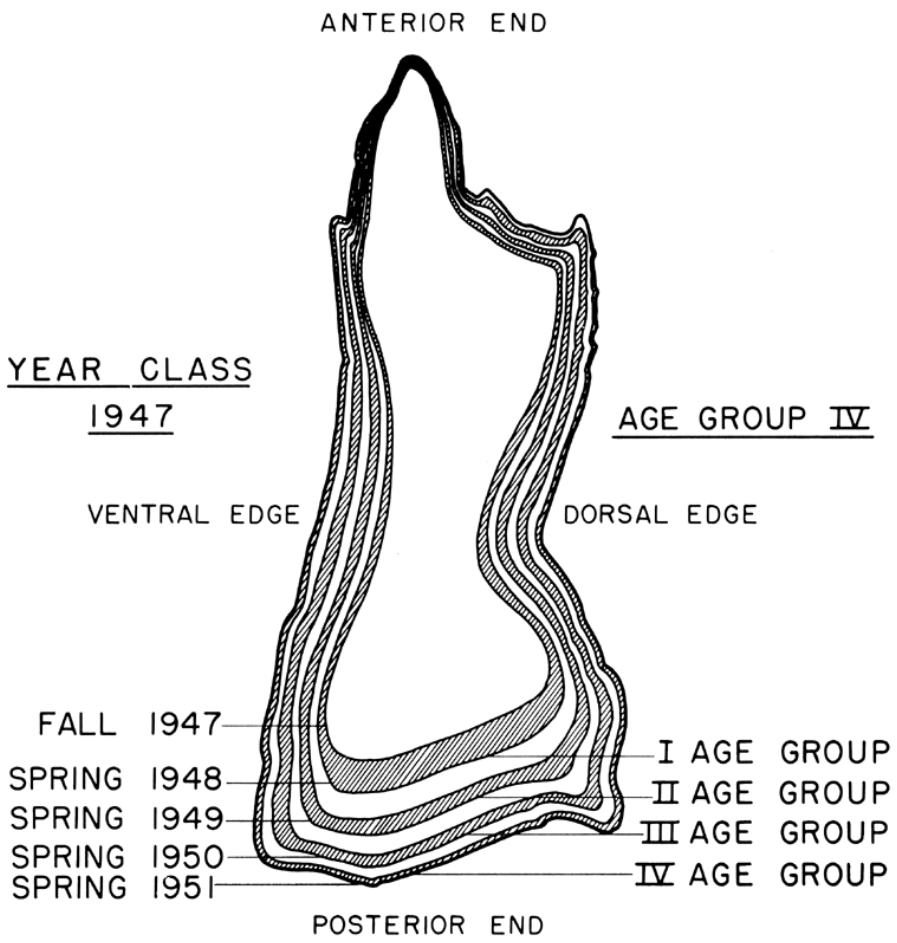

FIGURE 10. Hypothetical right otolith (sagitta) of Pacific mackerel

FIGURE 10. Hypothetical right otolith (sagitta) of Pacific mackerel

As the otoliths are removed from their storage envelopes for reading, the sample number, envelope number, and date of sample are noted on a sheet of tabulating paper. Upon determining the number of complete winter rings that information, too, is noted in its proper place on the same sheet of paper. Age "0" would be any fish taken in the first twelve months of its life prior to May 1. It would have one opaque zone (nucleus) in the center of the otolith and the margin would probably be translucent if taken after September. Age I would have two completed summer zones (nucleus and one band) with one completed winter ring between the two and a winter ring in the process of formation on the margin if taken after September (Figure 10). For each year's increase in age one summer and one winter ring is added in that order (Figures 4, 5, 6).

Each set of otoliths taken throughout the fishing season (normally from July or August through March) is carefully aged. These determinations are recorded for each age by month at quarter centimeter lengths and then weighted according to landings for that particular month. (See Appendix B.) This weighting is necessary in order to compensate for months during which landings were heavy and sampling was light or vice versa. These weighted figures are then cross-added for the months of a given fishing season and a sum derived at each length. These sums are then smoothed twice by a moving average of three. A percentage of fish at each length for each age is then determined from this smoothed frequency. This percentage when applied to the season summary frequency, as explained in Appendix A, determines the number of fish of each age at each length. This seems to be as accurate a method as possible of obtaining an estimate of the age composition of the catch of Pacific mackerel.

5. RESULTS

5.1. GENERAL INFORMATION

Mr. D. H. Fry, Jr. initiated the age determination work with the Pacific mackerel and completed readings through the 1940–41 season. Some of the information in this present paper for the fishing seasons 1939–40 and 1940–41 has been compiled from his data. The author has contributed the age data for all seasons subsequent to 1940–41. Before the readings of Fry could be incorporated with those of the author, it was necessary to determine if the two were comparable. All of the 1941–42 otoliths were therefore read by both individuals at different times and the results compared. This comparison (Figure 11) indicated that the

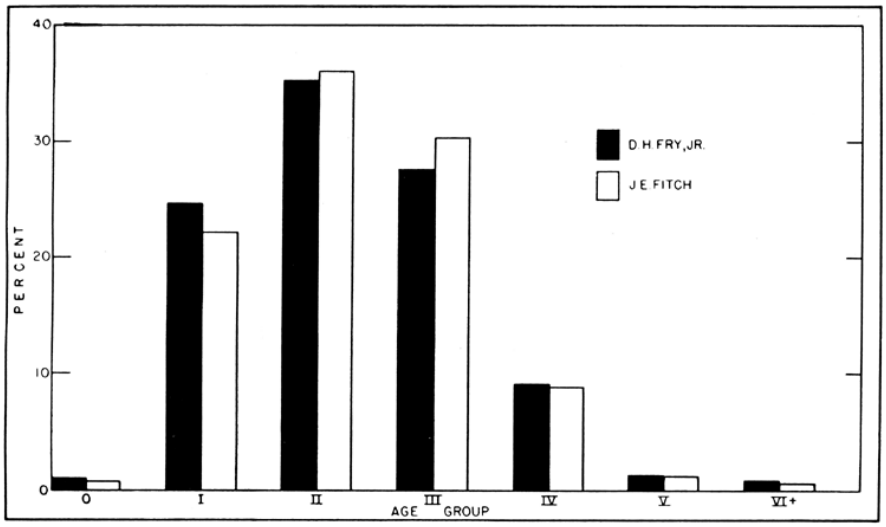

FIGURE 11. Comparison of the 1941-42 season otolith readings by D. H. Fry, Jr. and John E. Fitch. Fry read 2095 sets and Fitch 2303. This figure shows the percentage of the number read per individual which were placed in each age group.

FIGURE 11. Comparison of the 1941–42 season otolith readings by D. H. Fry, Jr. and John E. Fitch. Fry read 2095 sets and Fitch 2303. This figure shows the percentage of the number read per individual which were placed in each age group

differences between the two were so slight as to be not significant; therefore, Fry's readings were retained for calculating the age composition of the catch for the seasons 1939–40 and 1940–41.

5.2. UNREADABLE OTOLITHS

One always finds some unreadable otoliths. This logically leads to the question of whether or not the proportion is so great that the unread otoliths would have influenced any particular age group had they been readable. The reasons for this unreadability are several and varied. Frequently one or both otoliths will be badly disfigured by freakish deposits of calcium carbonate completely obliterating any marks which may have been present. With older otoliths calcification is often so heavy that the extent of the nucleus and possibly the first few rings cannot be distinguished. Many times the outermost bands on otoliths from older fish are so fine that the entire margin of the otolith assumes a translucent appearance making accurate reading impossible.

Most of the mackerel caught during any particular season are less than three years of age (Figure 12) and the otoliths of these fish are

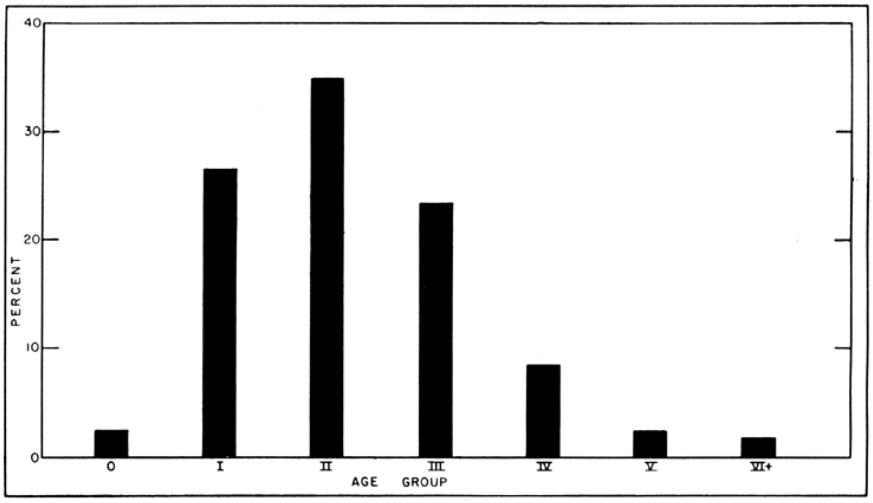

FIGURE 12. Percentage of number of mackerel landed age groups O through VI+, averaged for the 12 seasons 1939-40 through 1950-51

FIGURE 12. Percentage of number of mackerel landed age groups O through VI +, averaged for the 12 seasons 1939–40 through 1950–51

quite easily read. That more than 98 percent of the mackerel otoliths were readable was partially due to a method employed when older fish were encountered. This method consisted of grouping into one category all fish six years of age or older. This fact alone made it possible to accept many otolith readings which would have had to be rejected if it had been necessary to assign a definite age to all fish over five. The greatest age determined for any individual Pacific mackerel was 11 years.

of more than 21,000 pairs of otoliths examined in this study, slightly less than 2 percent have been found to be unreadable. Morrow (1951) found that 23 pairs of 760, or somewhat over 3 percent, were unreadable with the longhorn sculpin. Fridricksson (1934) reported on the degree of accuracy reached by four different investigators in independent age readings of 350 cod otoliths. Each of these four investigators read the same otoliths on two separate occasions, which gave a total of eight readings for each of 350 otoliths. Full agreement of all eight readings was obtained with 24 percent. With three investigators (three readings), greatest agreement was 62 percent. Agreement of a single reader with himself on the first and second readings varied between 58 and 82 percent. On both readings, all four investigators found 17.6 and 21.5 percent unreadable. Most of these otoliths showed eight or more complete winter rings.

5.3. AGE AND GROWTH RATE OF THE PACIFIC MACKEREL

Tables 1 through 12 show the length frequencies by age group for Pacific mackerel from which otoliths were removed during routine sampling. These tables cover fishing seasons 1939–40 through 1950–51. Tables 1 and 2 were prepared from age determinations made by D. H. Fry, Jr., while the remaining 10 represent otolith readings made by the author. The greatest number of otoliths read during a single season was 2,637 sets (1946–47). Except for the 1948–49 season, when 631 were read, more than 1,000 sets were examined during each of the 12 seasons covered by this report. In these tables only otoliths for which a definite age could be assigned have been tabulated. Many other otoliths not included in these tables, placed in age category VI plus, were used in calculating the number of fish of each age in the commercial catch. The otoliths tabulated at ages VII, VIII, and IX in Tables 1 through 12 were also lumped into the VI plus category for age composition calculations.

Table 13 was derived by summing Tables 1 through 12 at each length for each age. In all, 20,893 pairs of otoliths were read during the period 1939–40 through 1950–51. Two fish not included in this table were determined as 10 years of age and a single fish was 11. None has ever been examined by the author which was older than 11. The numbers of fish in each age group in this table are not proportional to the numbers of fish in the commercial catch (age composition). The otolith sampling technique as outlined in an earlier section precludes drawing conclusions as to the age composition of the commercial catch from unadjusted otolith readings.

TABLE 1

Frequency of Otoliths Read at Each Age for the 1939-40 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7										
8										
9										
80										
1										
2										
3										
4										
85										
6										
7										
8	2									
9										
90										
1	1									
2										
3	3	3								
4										
95										
6		1								
7	2									
8	1	5								
9	1	1								
100		10								
1	2	12								
2	1	11								
3	2	16								
4	3	8	1							
105		17								
6		17	1							
7	3	19	4							
8	1	27	5							
9	1	28	5							
110		29	4							
1	2	16	7							
2	1	24	5							
3		20	7							
4		15	6	1						
115		14	11	1						
6		7	13							
7		7	11	2						
8		10	18							
9		1	19	2						
120		4	14	6						

TABLE 1

Frequency of Otoliths Read at Each Age for the 1939–40 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

Table 1—Continued

Frequency of Otoliths Read at Each Age for the 1939-40 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		1	19	13						
2		3	18	6						
3		3	17	8	1					
4		3	23	14						
125		1	14	20						
6		1	17	26						
7			22	15						
8			6	32	1					
9		1	14	31	1					
130			14	30						
1			13	34	6					
2			5	31	2					
3			10	34	2					
4			7	28	4	1				
135			2	33	5					
6			5	22	9					
7			1	22	13	2				
8			1	18	10	1				
9			2	16	7	2				
140				12	9	2				
1				12	10	6				
2				9	14	1				
3			1	1	10	2				
4				2	12	2		1		
145				2	9	7				
6				1	5	9	1			
7					12	6	2			
8					5	7	6			
9				1	6	11	4			
150				1	2	6	4	2		
1					2	4	4	3		
2					1	5	4	2		
3						5	4	1	1	
4					2	6	4	2		
155						3	4	1		
6						2	2	1		
7							4	2	1	
8						1	2	2		
9							1	3		
160							1		3	
1							2	1		
2							4		1	
3							1	1		
4									1	
165										
166									1	
Sum	26	335	342	486	160	91	54	22	8	
Mean	101.2	109.3	122.5	131.5	141.1	147.8	153.6	154.7	160.3	

TABLE 1

Frequency of Otoliths Read at Each Age for the 1939–40 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 2

Frequency of Otoliths Read at Each Age for the 1940-41 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7										
8										
9										
80										
1										
2										
3										
4										
85										
6										
7	1									
8										
9	1									
90	2									
1	1	1								
2	1									
3	2									
4	7									
95	2	2								
6		2								
7	4	2								
8	3	2								
9	4	3								
100		3								
1	3	3								
2	5	7	2							
3	1	9	1							
4	2	7	1							
105	4	13								
6	6	13	1							
7	5	13	2							
8	1	17	6							
9		17	8							
110	1	16	16							
1		25	21	2						
2		31	26							
3		23	35	1						
4		26	44							
115		22	53	2						
6		12	59	5						
7		16	56	8						
8		9	71	8	1					
9		9	78	2	1					
120		9	58	8	1					

TABLE 2

Frequency of Otoliths Read at Each Age for the 1940–41 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 2—Continued

Frequency of Otoliths Read at Each Age for the 1940-41 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		3	76	10						
2		1	64	2	4					
3		1	63	8	1					
4		2	65	21	3					
125		2	51	19						
6			46	25	4					
7			33	27	5					
8			29	34	5					
9		1	30	29	9	2				
130			13	37	9					
1		1	11	35	7					
2			8	36	19					
3			8	31	13	1				
4			2	33	20	1				
135			1	16	17	1				
6			2	23	22	1				
7				12	19					
8				15	17					
9				10	18	3				
140				11	22					
1				3	17					
2				1	14	3				
3				5	7	1				
4				4	8	3	1			
145					12	3	1			
6					7	5				
7					6	3	1			
8					2	6	2	1		
9					2	2				
150					3	2	1			
1						2	1			
2						1	1			
3					3	3	1			
4										
155							1			
6										
7							1			
8										
9						1				
160										
1							1			
2										
3										
4								1		
165										
166										
Sum	56	323	1040	483	298	44	12	2		
Mean	99.7	111.1	120.2	130.0	136.9	145.0	150.9	156.0		

TABLE 2

Frequency of Otoliths Read at Each Age for the 1940–41 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 3

Frequency of Otoliths Read at Each Age for the 1941-42 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7	1									
8										
9	1									
80										
1										
2	2									
3										
4	1									
85	1									
6	1									
7	1									
8	2									
9	2									
90										
1	2									
2										
3	2	1								
4	2									
95										
6		1								
7		2								
8		3								
9		5								
100		2								
1		11								
2		3								
3		9								
4		8								
105		10								
6		15	1							
7		31								
8		21	1							
9		35	3							
110		48	2							
1		42	16							
2		64	17							
3		48	26							
4		49	28							
115		35	34							
6		18	54	1						
7		23	43	1						
8		13	60	3						
9		14	63	4						
120		3	65	7	1					

TABLE 3

Frequency of Otoliths Read at Each Age for the 1941–42 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 3—Continued

Frequency of Otoliths Read at Each Age for the 1941-42 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		1	84	12						
2		4	65	10						
3			60	25	1					
4			58	34						
125			56	31						
6			38	44	1					
7			32	61						
8			34	71						
9			18	74	2					
130			10	75	5					
1			6	79	3					
2			4	58	4					
3			2	64	4					
4				56	8					
135			1	22	9					
6				26	18	1				
7				15	16	2				
8				12	14	1				
9				9	12					
140				8	7					
1				5	13	2				
2				2	11	3				
3				1	10	2				
4					16	2				
145				2	4					
6				1	12	2				
7					7	1				
8					2	2				
9					3	1				
150					1	2				
1						1				
2					1					
3								1		
4							1			
155						3				
6										
7							1			
8						1		1		
9										
160										
1										
2										
3										
4										
165										
166										
Sum	18	519	881	813	185	26	2	2		
Mean	87.3	111.1	120.7	129.9	139.3	145.7	155.5	155.5		

TABLE 3

Frequency of Otoliths Read at Each Age for the 1941–42 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 4

Frequency of Otoliths Read at Each Age for the 1942-43 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7										
8										
9										
80										
1										
2										
3										
4										
85										
6										
7										
8										
9										
90										
1										
2										
3		2								
4		1								
95										
6		2								
7		2								
8		7								
9		13								
100		11								
1		29								
2		28								
3		37								
4		37								
105		49								
6		46								
7		27								
8		43								
9		36								
110		32								
1		35								
2		25	3							
3		29	3							
4		20	3							
115		18	4							
6		20	3							
7		15	9							
8		13	7							
9		10	12							
120		4	8	1						

TABLE 4

Frequency of Otoliths Read at Each Age for the 1942–43 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 4—Continued

Frequency of Otoliths Read at Each Age for the 1942-43 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		3	10							
2		1	16		1					
3		2	16	2						
4			20	6						
125			24	4						
6			13	17		1				
7			17	9	1					
8			14	12		1				
9			12	25	2					
130			10	26	2					
1			7	30						
2			3	24	1					
3			2	28	4					
4				21	9					
135				19	12					
6			1	22	10					
7				25	12	1				
8				25	14	1				
9				9	5					
140				4	12	1	1			
1				4	8	1				
2				2	13	2				
3				2	8	1				
4					5					
145					4	2				
6					2	2				
7					1	1				
8					3	4				
9						2				
150							1			
1						2				
2										
3										
4						1	1			
155										
6										
7										
8										
9										
160										
1								1		
2										
3										
4										
165										
166										
Sum		597	217	317	129	23	3	1		
Mean		108.0	123.8	132.6	138.5	144.0	148.0	161.0		

TABLE 4

Frequency of Otoliths Read at Each Age for the 1942–43 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 5

Frequency of Otoliths Read at Each Age for the 1943-44 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7										
8										
9										
80										
1										
2										
3										
4										
85										
6										
7										
8										
9	1									
90										
1										
2										
3	1									
4										
95										
6	2									
7										
8										
9	2	1								
100	3									
1	1									
2		1								
3										
4		1								
105										
6		1								
7		1	1							
8		2	2							
9		4	1							
110		9	5							
1		16	10							
2		22	22							
3		33	19							
4		36	37							
115		37	83							
6		40	98							
7		38	113							
8		45	126	1						
9		32	135							
120		10	131							

TABLE 5

Frequency of Otoliths Read at Each Age for the 1943–44 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 5—Continued

Frequency of Otoliths Read at Each Age for the 1943-44 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
1		3	137							
2			103							
3			101							
4			85							
125			69	1						
6			54	2						
7			47	10						
8			31	20						
9			14	22						
130			17	19						
1			9	26	1					
2			3	20						
3			1	23	2					
4			1	26	2		1			
135			1	15	7					
6			1	20	6					
7				15	11					
8				9	22					
9				7	16	1				
140				5	23	1				
1				3	15	2				
2				2	16	1				
3				1	18	1				
4					12		1			
145					8	3				
6					6	3				
7					4	6				
8					3	1				
9					2		1			
150						4	1			
1										
2						1				
3										
4										
155										
6				1				1		
7										
8										
9										
160										
1										
2										
3								1		
4										
165										
166										
Sum	10	332	1457	248	174	24	4	2		
Mean	97.3	115.2	120.3	132.8	140.6	145.9	144.3	159.5		

TABLE 5

Frequency of Otoliths Read at Each Age for the 1943–44 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 6

Frequency of Otoliths Read at Each Age for the 1944-45 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7										
8										
9										
80										
1										
2										
3										
4										
85										
6										
7										
8										
9										
90										
1										
2										
3										
4										
95										
6										
7										
8										
9										
100										
1		1								
2		1								
3		7								
4		3								
105		12								
6		6								
7		8								
8		19								
9		19								
110		29								
1		23								
2		36								
3		36								
4		33								
115		31	1							
6		24	4							
7		31	5							
8		21	16							
9		11	14							
120		8	20							

TABLE 6

Frequency of Otoliths Read at Each Age for the 1944–45 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 6—Continued

Frequency of Otoliths Read at Each Age for the 1944-45 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
1		1	18							
2		1	20							
3			39	1						
4			40	2						
125			30	7						
6			40	19						
7			32	26						
8			29	43						
9			25	38						
130			19	49	1					
1			6	56	2					
2			1	61						
3				64	1					
4				41	1					
135				62	3					
6				29	3					
7				34	6					
8				27	12					
9				23	12					
140				16	15	1				
1				10	11					
2				4	19	1				
3				1	21	1				
4					19	1				
145					13	7	1			
6					6	2				
7					5	5				
8					3	2				
9					1	4				
150						3	1			
1						1				
2							1			
3										
4										
155										
6										
7										
8										
9										
160										
1										
2							1			
3									1	
4										
165										
166										
Sum		361	359	613	154	28	4	0	1	
Mean		112.7	124.4	132.7	141.5	146.6	152.2		163.0	

TABLE 6

Frequency of Otoliths Read at Each Age for the 1944–45 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 7

Frequency of Otoliths Read at Each Age for the 1945-46 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7										
8										
9										
80										
1	1									
2	4									
3	6									
4	3									
85	9									
6	3									
7	6									
8	9									
9	7									
90	4	1								
1	1									
2	4	1								
3	5	1								
4	8									
95	3	5								
6		10								
7	1	14								
8	3	17								
9		36								
100	1	12								
1		14								
2		22								
3		27								
4		19								
105		27								
6		34								
7		33								
8		35								
9		36								
110		35								
1		29								
2		37	1							
3		20								
4		32	3							
115		27	3							
6		27	3							
7		14	11							
8		14	19							
9		7	26							
120		2	21							

TABLE 7

Frequency of Otoliths Read at Each Age for the 1945–46 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 7—Continued

Frequency of Otoliths Read at Each Age for the 1945-46 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1			21							
2			29							
3			27	1						
4			33	1						
125			45							
6			38	2						
7			50	5						
8			34	9						
9			38	17						
130			25	26						
1			20	28	1					
2			12	21						
3			3	27	3					
4				34	1					
135			1	24	3					
6				33	3	1				
7				36	7	1				
8				21	9					
9				23	15	1				
140				14	26					
1				13	34	1				
2				6	30	4				
3					42	5				
4					34	4	1			
145					27	6	1			
6				1	19	7				
7					25	13	3			
8					22	14	2			
9					7	13	2			
150					6	45	10		1	
1					4	27	15	1		
2					1	19	8	3		
3						13	14	1		
4						6	5	4	4	
155						4	7	3	1	
6						1	5	2		
7							1	2		
8									1	1
9										1
160								4	3	
1								1		1
2								2	1	
3									1	
4										
165										
166										1
Sum	78	588	463	342	319	185	74	23	12	4
Mean	88.9	107.7	124.8	134.5	143.1	149.3	151.9	156.2	157.0	161.0

TABLE 7

Frequency of Otoliths Read at Each Age for the 1945–46 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 8

Frequency of Otoliths Read at Each Age for the 1946-47 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
68										
9	1									
70										
1	1									
2										
3										
4	3									
75										
6	2									
7										
8										
9	4									
80	2									
1	2									
2	3									
3	1									
4	6									
85	3									
6	5									
7	11									
8	12									
9	6									
90	13									
1	12									
2	8									
3	5									
4	5									
95	4									
6	7									
7	2									
8	3									
9	5	3								
100	2	1								
1	2	3								
2	1	5								
3		6								
4		18								
105	1	28								
6		34								
7		55								
8		59								
9		85								
110		30								
1		25	1							
2		34	1							
3		43	3							
4		46	5							
115		37	6							
6		49	16							
7		35	31							
8		30	35							
9		20	44							
120		8	29	1						

TABLE 8

Frequency of Otoliths Read at Each Age for the 1946–47 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 8—Continued

Frequency of Otoliths Read at Each Age for the 1946-47 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		8	37	1						
2		7	36							
3			63	2						
4			53							
125			65							
6			68	1						
7			69	6						
8			65	13						
9			41	15						
130			54	49						
1			40	58						
2			23	40						
3			15	42						
4			7	35	1	1				
135			3	29	3	1				
6			3	29	2					
7				27	5	1				
8				29	8	1				
9				26	10	3				
140				17	26	2	1			
1				9	25	2				
2				6	26	6				
3				5	30	7	2	1		
4				2	27	16	2			
145				1	23	13	3		1	
6					21	11	1			
7					21	19	4	1		
8					19	15	1			
9					8	6	2	1		
150					6	18	11	5		
1					4	22	12	5	1	
2					3	12	8	4	3	
3						3	8	7	1	
4						6	3	4	1	2
155						4	4	3	2	1
6					1	1	5	2		
7						1	1	3	3	
8							2	2	2	
9							1			1
160							2	2	1	
1								4	1	
2						1				
3									1	
4										1
165										
166										
Sum	132	669	813	443	269	172	73	44	17	5
Mean	89.3	111.3	124.8	133.9	143.6	147.7	151.3	153.8	155.3	157.2

TABLE 8

Frequency of Otoliths Read at Each Age for the 1946–47 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 9

Frequency of Otoliths Read at Each Age for the 1947-48 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
66										
67	1									
68										
69	1									
70										
71										
72	1									
73										
74	2									
75	4									
6	5									
7	13									
8	12									
9	9									
80	9									
1	11									
2	13									
3	11									
4	10									
85	5									
6	5									
7	9									
8	9									
9	10									
90	9									
1	10									
2	5									
3	5									
4	6									
95	11	1								
6	5									
7	6									
8	8									
9	3									
100	8	1								
1	6									
2	3									
3	1	2								
4	6	4								
105	1	5								
6	1	5								
7	1	3								
8		2								
9		5	1							
110		6								
1		1								
2		8								
3		7	1							
4		8	1							
115		8								
6		18	3							
7		11	5							
8		8	15	1						
9		20	22							
120		3	8							

TABLE 9

Frequency of Otoliths Read at Each Age for the 1947–48 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 9—Continued

Frequency of Otoliths Read at Each Age for the 1947-48 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		3	3							
2		6	14	1						
3		3	15	2						
4		3	16							
125		3	17	5						
6		2	25	6						
7			34	7						
8		1	36	11						
9			37	12						
130			20	12	1					
1			14	24						
2			10	20	1					
3			14	23	2					
4			7	19	4					
135			7	21	2					
6			6	22	1					
7				16	3					
8				17	7	2				
9				16	4					
140				12	21	3				
1				15	22	3	2			
2				9	15	5				
3				3	11	3	1			
4				10	15	6	1			
145				4	11	4	1			
6				2	13	6	1	1		
7				2	18	5	1			
8					7	5	2			
9					3	5	2			
150					12	16	7	3	1	
1					7	10	5	1		
2					4	8	9	2	1	
3					4	10	5	3		
4					2	4	7	1	1	
155					1	3	6	2	1	
6						5		3		
7					1	1	2	2	1	
8						1	2			
9							2	1		
160						1	2	2		
1						2	2	1	1	
2						2				
3						1			1	
4										
165										
166										
Sum	235	147	331	292	192	111	60	22	7	0
Mean	87.6	114.9	126.3	134.8	143.9	149.5	152.3	154.4	156.0	

TABLE 9

Frequency of Otoliths Read at Each Age for the 1947–48 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 10

Frequency of Otoliths Read at Each Age for the 1948-49 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
70										
1										
2										
3	1									
4										
75										
6	1									
7	1									
8	1									
9										
80										
1	2									
2	1									
3	2									
4	3									
85										
6										
7	4									
8	4									
9	5									
90										
1	3									
2		1								
3	1	4								
4		10								
95		2								
6		6								
7		9								
8		17								
9		29								
100		8								
1		20								
2		15								
3		16								
4		27								
105		9								
6		25								
7		18								
8		24								
9		10								
110		20								
1		28								
2		10								
3		16								
4		10	1							
115		24								
6		14	1							
7		8	7							
8		8	8							
9		2	8							
120		5	10							

TABLE 10

Frequency of Otoliths Read at Each Age for the 1948–49 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 10—Continued

Frequency of Otoliths Read at Each Age for the 1948-49 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
1			9							
2		2	10							
3			10							
4			11							
125			10							
6			4							
7			2							
8			3	1						
9			2							
130				4						
1			1	2						
2				1						
3				3						
4				6	1					
135				1						
6				4						
7				2						
8				6	2					
9				5	1					
140				2						
1				1	9					
2				1	4					
3					7					
4					2					
145					4					
6					4	2				
7					3	1				
8					4	4				
9					1	2				
150						3				
1					1		1			
2						1	2			
3							3			
4						1				
155										
6										
7							1	1		
8						1				
9									1	
160								1		
1										
2										
3										
4								1		
165										
166										
Sum	29	397	97	39	43	15	7	3	1	
Mean	85.4	106.6	121.9	135.5	143.5	149.5	153.0	160.3	159.0	

TABLE 10

Frequency of Otoliths Read at Each Age for the 1948–49 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 11

Frequency of Otoliths Read at Each Age for the 1949-50 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
67	1									
68										
69										
70										
71										
72										
73										
74										
75	1									
6										
7										
8	1									
9										
80										
1										
2										
3										
4	2									
85	1									
6	1									
7		2								
8	2	3								
9	1	1								
90	1	2								
1		2								
2		5								
3	1	12								
4	1	21	1							
95		25	1							
6	1	21								
7		21	1							
8		29								
9		38								
100		46								
1		38	1							
2		44	1							
3		35	3							
4		36	4							
105		29	4							
6		24	6							
7		29	11							
8		25	19							
9		20	35							
110		16	29							
1		8	25							
2		3	33							
3		4	57							
4		3	54							
115		1	41							
6		1	55							
7			44							
8			48							
9			38	1						
120			45							

TABLE 11

Frequency of Otoliths Read at Each Age for the 1949–50 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 11—Continued

Frequency of Otoliths Read at Each Age for the 1949-50 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
1			66							
2			48	3						
3			44	2						
4			35	3						
125			22	8						
6			50	11						
7			25	12						
8			18	15						
9			10	16						
130			9	21						
1			12	31	1					
2			1	23						
3			2	13						
4				19	1					
135				9	2					
6			1	13	2					
7				11						
8				7	3					
9				3	2					
140				4	7					
1					7					
2					9					
3				2	5					
4					10	2				
145					9	1				
6					5					
7					4	7	1			
8					4	6	1			
9					1	6	2			
150					2	4				
1					2	8	1			
2						3	1			
3						2				
4										
155						4	1	1		
6						3	4			
7							6			
8						2	1			
9										
160										
1						1				1
2							2		1	
3										
4								1		
165								1		
166								1		
Sum..	14	544	899	227	76	49	20	4	1	1
Mean.	85.5	101.7	118.0	131.4	143.0	150.6	155.0	162.5	162.0	161.0

TABLE 11

Frequency of Otoliths Read at Each Age for the 1949–50 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 12

Frequency of Otoliths Read at Each Age for the 1950-51 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	O	I	II	III	IV	V	VI	VII	VIII	IX
75										
6										
7										
8										
9										
80	1									
1										
2										
3										
4										
85										
6										
7										
8										
9										
90										
1										
2										
3		1								
4										
95										
6										
7										
8										
9		2	1							
100		6								
1		4	1							
2		7	1							
3		1	2							
4		9	1							
105		7								
6		6	2							
7		9	2							
8		4	8							
9		11	9							
110		18	10							
1		5	8							
2		10	12							
3		8	20							
4		8	19							
115		9	32	1						
6		7	21	1						
7		4	23							
8		4	26	1						
9		4	22	4						
120		2	24	3						

TABLE 12

Frequency of Otoliths Read at Each Age for the 1950–51 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 12—Continued

Frequency of Otoliths Read at Each Age for the 1950-51 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		2	23	5						
2		1	19	4						
3			28	19						
4			15	13						
125			7	11						
6			14	19						
7			9	17						
8			11	28	1					
9			5	19						
130			1	23						
1			3	32	2					
2			2	30	1					
3			1	25		1				
4			2	18	1					
135			2	13	3					
6				27	11					
7				25	8					
8				19	2					
9				9	4					
140				7	4					
1				8	10					
2				4	5	2				
3				2	4					
4				1	9	1				
145					1					
6						1				
7					3	1				
8					1					
9					1	2				
150							2			
1						2	2			
2						1				
3					1		1			
4						1				
155							1	1		
6							1			
7										
8										
9									1	
160							1			
1							1			
2										
3										
4										
165										
166										
Sum	1	149	386	388	72	12	9	1	1	
Mean	80.0	109.7	118.4	131.2	139.9	146.7	154.1	155.0	159.0	

TABLE 12

Frequency of Otoliths Read at Each Age for the 1950–51 Season. Length of Fish From Which Otoliths Were Taken Is in Quarter Centimeters

TABLE 13

Summary of Tables 1 Through 12 Showing Frequency of All Otoliths for Which a Definite Age Could Be Assigned, Season 1939-40 Through 1950-51

½cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
67	2									
68										
69	2									
70										
71	1									
72	1									
73	1									
74	5									
75	5									
6	8									
7	15									
8	14									
9	14									
80	12									
1	16									
2	23									
3	20									
4	25									
85	19									
6	15									
7	32	2								
8	40	3								
9	33	1								
90	29	3								
1	30	3								
2	18	7								
3	25	24								
4	29	32	1							
95	20	35	1							
6	15	43								
7	15	50	1							
8	18	80								
9	15	131	1							
100	14	100								
1	14	135	2							
2	10	144	4							
3	4	165	6							
4	11	177	7							
105	6	206	4							
6	7	226	11							
7	9	246	20							
8	2	278	41							
9	1	306	62							
110	1	288	66							
1	2	253	88	2						
2	1	304	120							
3		287	171	1						
4		286	201	1						
115		263	268	4						
6		237	330	7						
7		202	358	11						
8		175	449	14	1					
9		130	481	13	1					
120		58	433	26	2					

TABLE 13

Summary of Tables 1 Through 12 Showing Frequency of All Otoliths for Which a Definite Age Could Be Assigned, Season 1939–40 Through 1950–51

TABLE 13—Continued

Summary of Tables 1 Through 12 Showing Frequency of All Otoliths for Which a Definite Age Could Be Assigned, Season 1939-40 Through 1950-51

¼cm	AGE GROUP									
	0	I	II	III	IV	V	VI	VII	VIII	IX
1		25	503	41						
2		26	442	26	5					
3		9	483	70	3					
4		8	454	94	3					
125		6	410	106						
6		3	407	172	5	1				
7			372	195	6					
8		1	310	289	7	1				
9		2	246	298	14	2				
130			192	371	18					
1		1	142	435	23					
2			72	365	28					
3			58	377	31	2				
4			26	336	53	3	1			
135			18	264	66	2				
6			19	270	87	3				
7			1	240	100	7				
8			1	205	120	6				
9			2	156	106	10				
140				112	172	10	2			
1				83	181	17	2			
2				46	176	28				
3			1	23	173	23	3	1		
4				19	169	37	6	1		
145				9	125	46	7		1	
6				5	100	50	3	1		
7				2	109	68	12	1		
8					75	66	14	1		
9				1	35	54	13	1		
150				1	32	103	38	10	2	
1					20	79	41	10	1	
2					10	51	34	11	4	
3					8	36	36	13	2	
4					4	25	21	11	6	2
155					1	21	24	11	4	1
6				1	1	12	17	9		
7					1	2	17	10	5	
8						6	7	5	3	1
9						1	4	4	2	2
160						1	6	9	7	
1						3	6	8	2	2
2						3	7	2	3	
3						1	1	2	4	
4								3	1	1
165								1		
166								1	1	1
Sum	599	4961	7285	4691	2071	780	322	126	48	10
Mean	89.9	107.3	121.5	132.0	141.1	148.1	152.2	155.1	157.1	159.1

TABLE 13

Summary of Tables 1 Through 12 Showing Frequency of All Otoliths for Which a Definite Age Could Be Assigned, Season 1939–40 Through 1950–51

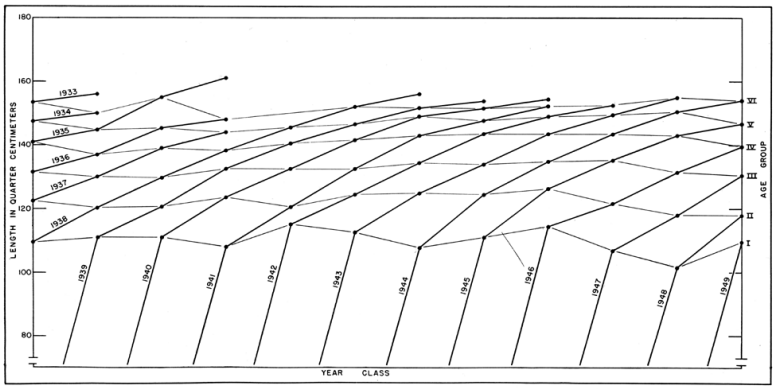

FIGURE 13. Growth curves of various year classes based upon otolith readings only. Zero age group has not been included for any year class.

FIGURE 13. Growth curves of various year classes based upon otolith readings only. Zero age group has not been included for any year class

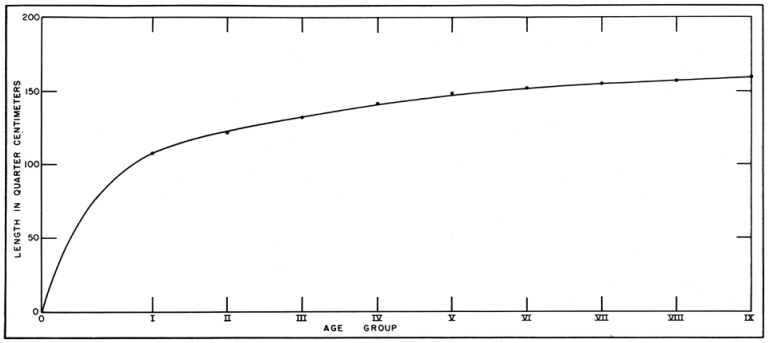

FIGURE 14. Growth curve of Pacific mackerel based upon mean lengths of age groups in Table 13. Zero age group has not been included for reasons outlined in text.

FIGURE 14. Growth curve of Pacific mackerel based upon mean lengths of age groups in Table 13. Zero age group has not been included for reasons outlined in text

Figure 13 (growth curves for individual year classes) was derived from mean values of otolith readings at each age in Tables 1 through 12. Age zero has not been included in these curves because mackerel less than 12 months of age are not generally taken by the fishermen. The 1947–48 season was an exception. Those taken are usually large specimens and seldom present a true picture of the zero age group. The smallest fish of the year usually escape through the mesh of the nets used in the Pacific mackerel fishery.

The smaller average sizes of the one year old fishes in the 1947 and 1948 year classes are attributed in part at least to the fact that recruitment in these years was extremely good. Schools of these small mackerel were exceptionally large and dense, causing competition for food within the individual schools to be keen. This is in turn reflected in the growth of the individual fish, since rate of growth is more or less in direct proportion to food intake and metabolism. Phillips (1948) has demonstrated that in a reduced sardine population the average growth rate increased. The growth curve (Figure 14) has been derived by averaging all of the otolith readings for each age (Table 13). Zero year old fish have not been included, as previously explained, for Figure 13.

Figure 15 superimposes age data on the weight-length curve for the Pacific mackerel. From this it may be seen that a 12-inch fish is two years of age and weighs about three-quarters of a pound. The mackerel does not attain a length of 15 inches until six years of age. At this length and age the weight has increased to one and one-half pounds. Fry (1936b)

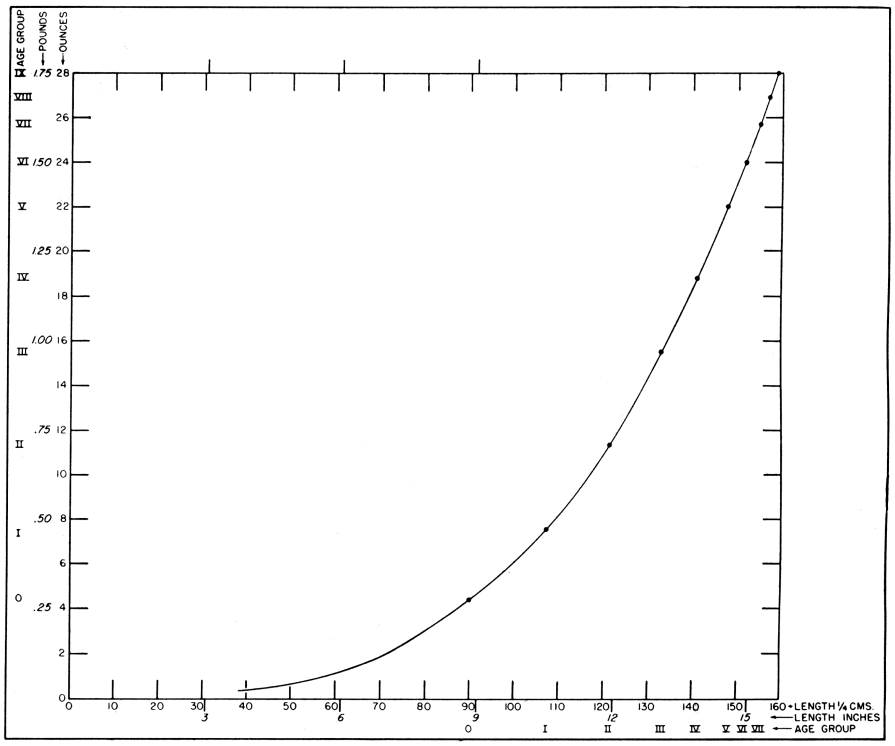

FIGURE 15. Weight-length-age relationship for Pacific mackerel

FIGURE 15. Weight-length-age relationship for Pacific mackerel

TABLE 14

Weight-Length Chart for Pacific Mackerel Based on Average Weights at Each Length
Figures determined by D. H. Fry, Jr.

¼ cm	Grams	¼ cm	Grams	¼ cm	Grams
30	----------	80	80.5	130	422.
1	----------	1	84.0	1	433.
2	----------	2	87.5	2	444.
3	----------	3	91.5	3	455.
4	5.0	4	95.5	4	466.
35	5.5	85	99.0	135	477.
6	6.0	6	103.	6	489.
7	6.5	7	107.	7	500.
8	7.0	8	111.	8	512.
9	7.6	9	115.	9	522.
40	8.2	90	119.	140	532.
1	9.0	1	123.	1	542.
2	9.8	2	127.	2	552.
3	10.7	3	131.	3	562.
4	11.7	4	135.	4	572.
45	12.6	95	139.	145	582.
6	13.6	6	144.	6	593.
7	14.6	7	148.	7	606.
8	15.7	8	153.	8	619.
9	16.8	9	157.	9	633.
50	17.9	100	162.	150	648.
1	19.1	1	167.	1	664.
2	20.4	2	173.	2	681.
3	21.8	3	178.	3	699.
4	23.2	4	184.	4	718.
55	24.7	105	191.	155	736.
6	26.3	6	199.	6	755.
7	28.0	7	207.	7	768.
8	29.8	8	216.	8	782.
9	31.6	9	224.	9	793.
60	33.5	110	232.	160	804.
1	35.4	1	240.	1	817.
2	37.3	2	248.	2	830.
3	39.1	3	256.	3	849.
4	41.0	4	264.	4	869.
65	43.0	115	273.	165	884.
6	45.0	6	282.	6	899.
7	47.0	7	291.	7	909.
8	49.0	8	300.	8	919.
9	51.0	9	309.	9	928.
70	53.0	120	318.	170	938.
1	55.2	1	327.	1	----------
2	57.5	2	336.	2	----------
3	60.0	3	346.	3	----------
4	62.5	4	356.	4	----------
75	65.5	125	367.	175	----------
6	68.5	6	379.	6	----------
7	71.5	7	389.	7	----------
8	74.5	8	400.	8	----------
9	77.5	9	411.	9	----------

TABLE 14

Weight-Length Chart for Pacific Mackerel Based on Average Weights at Each Length Figures determined by D. H. Fry, Jr.

has previously given a brief explanation of the weight-length relationship of the Pacific mackerel. Table 14 presents weight-length data for all mackerel between 34 and 170 quarter centimeters. These values were determined by D. H. Fry, Jr.

5.4. AGE COMPOSITION OF THE MACKEREL CATCH

Table 15 shows the calculated number of fish landed for each age for seasons 1939–40 through 1950–51. Season 1939–40 from Fry's calculations is rounded off to the nearest 10,000 fish, while the remainder of the seasons have been rounded off to the nearest 1,000 fish.

TABLE 15
Calculated Number of Fish Landed for Ages 0 Through VI+ for Seasons 1939-40 Through 1950-51
Percentage of Seasons Contribution by Numbers and Year Class Are Also Indicated

	AGE GROUP							Totals
	0	I	II	III	IV	V	VI+	
1939-40 season								
Year class	1939	1938	1937	1936	1935	1934	----------	
No. of fish	2,960,000	25,200,000	26,540,000	35,130,000	10,570,000	5,340,000	6,100,000	111,840,000
Percent of landings	2.7	22.5	23.7	31.4	9.4	4.8	5.5	100.0
1940-41 season								
Year class	1940	1939	1938	1937	1936	1935	----------	
No. of fish	2,313,000	20,793,000	69,322,000	25,261,000	13,551,000	1,443,000	1,654,000	134,337,000
Percent of landings	1.7	15.5	51.6	18.8	10.1	1.1	1.2	100.0
1941-42 season								
Year class	1941	1940	1939	1938	1937	1936	----------	
No. of fish	398,000	12,507,000	26,454,000	25,661,000	5,121,000	970,000	549,000	71,660,000
Percent of landings	0.6	17.4	36.9	35.8	7.1	1.4	0.8	100.0
1942-43 season								
Year class	1942	1941	1940	1939	1938	1937	----------	
No. of fish	----------	29,376,000	9,204,000	12,698,000	5,271,000	822,000	260,000	57,631,000
Percent of landings	----------	51.0	16.0	22.0	9.1	1.4	0.5	100.0
1943-44 season								
Year class	1943	1942	1941	1940	1939	1938	----------	
No. of fish	836,000	12,462,000	54,106,000	10,156,000	7,133,000	1,082,000	394,000	86,169,000
Percent of landings	1.0	14.5	62.8	11.8	8.3	1.2	0.4	100.0
1944-45 season								
Year class	1944	1943	1942	1941	1940	1939	----------	
No. of fish	----------	16,556,000	19,047,000	33,905,000	7,712,000	1,616,000	444,000	79,280,000
Percent of landings	----------	20.9	24.0	42.8	9.7	2.0	0.6	100.0

TABLE 15

Calculated Number of Fish Landed for Ages 0 Through VI+ for Seasons 1939–40 Through 1950–51 Percentage of Seasons Contribution by Numbers and Year Class Are Also Indicated

1945-46 season								
Year class	1945	1944	1943	1942	1941	1940		
No. of fish	556,000	14,302,000	10,327,000	10,259,000	10,312,000	3,328,000	1,468,000	50,552,000
Percent of landings	1.1	28.3	20.4	20.3	20.4	6.6	2.9	100.0
1946-47 season								
Year class	1946	1945	1944	1943	1942	1941		
No. of fish	560,000	9,330,000	25,823,000	11,872,000	4,661,000	2,294,000	2,507,000	57,047,000
Percent of landings	1.0	16.4	45.2	20.8	8.2	4.0	4.4	100.0
1947-48 season								
Year class	1947	1946	1945	1944	1943	1942		
No. of fish	7,181,000	1,377,000	7,980,000	10,943,000	5,087,000	2,019,000	1,551,000	36,138,000
Percent of landings	19.8	3.8	22.1	30.3	14.1	5.6	4.3	100.0
1948-49 season								
Year class	1948	1947	1946	1945	1944	1943		
No. of fish	1,061,000	63,330,000	3,175,000	756,000	1,105,000	429,000	292,000	70,148,000
Percent of landings	1.5	90.3	4.5	1.1	1.6	0.6	0.4	100.0
1949-50 season								
Year class	1949	1948	1947	1946	1945	1944		
No. of fish	136,000	21,818,000	49,255,000	4,279,000	688,000	584,000	307,000	77,067,000
Percent of landings	0.2	28.3	63.9	5.5	0.9	0.8	0.4	100.0
1950-51 season								
Year class	1950	1949	1948	1947	1946	1945		
No. of fish	6,000	3,854,000	19,228,000	15,826,000	937,000	72,000	140,000	40,063,000
Percent of landings	0.0	9.6	48.0	39.5	2.3	0.2	0.4	100.0

TABLE 15—Cont'd.

Landings of nearly 137,000,000 fish during 1940–41 represent the best single season covered by this report. During only one other season, 1939–40, were more than 100,000,000 fish landed. Poorest landings were recorded in 1947–48, when about 36,000,000 fish were brought in. During most of the years between 50 and 80 million mackerel were caught per season.

The percentage of numbers of fish furnished by each year class by season of landing is also presented in this table. The 1941 year class, an abundant group, furnished but six-tenths of 1 percent of the 1941–42 total landings when they were zero year fish, while the other highly successful year class, that of 1947, furnished 19.8 percent of the 1947–48 landings when they were age zero. From the weight-length-age chart (Figure 15), it may be seen that age zero fish are about nine inches long and weigh but slightly more than one-quarter pound each. The 7,000,000 fish (Table 15) of the 1947 year class, taken before they were 12 months old, weighed less than one and one-half million pounds (Table 17). Disregarding natural mortality, these would have weighed more than three million pounds if landed as one-year-olds instead of zeros and more than five and a quarter million pounds if allowed to survive for but two additional years.

Landings in numbers of fish by year class are given in Table 16. These include calculated numbers of fish in age groups zero through five for all year classes on which complete data are available. Totals indicate that the 1947 year class contributed over 135,000,000 fish through only the first four years. This is 5,000,000 more fish than was contributed by the 1941 year class in six years, and 8,000,000 more than its next closest rival, the 1938 year class, for which information is lacking on the zero age group. Undoubtedly several millions more will be contributed by the 1947 year class during the next two seasons.

TABLE 16

Number of Fish Landed by Year Class at Each Age Group From 0 Through V

Year class	AGE GROUP						Totals
	0	I	II	III	IV	V	
1934	----------	----------	----------	----------	----------	5,340,000	----------
1935	----------	----------	----------	----------	10,570,000	1,443,000	----------
1936	----------	----------	----------	35,130,000	13,551,000	970,000	----------
1937	----------	----------	26,540,000	25,261,000	5,121,000	822,000	----------
1938	----------	25,200,000	69,322,000	25,661,000	5,271,000	1,082,000	126,536,000
1939	2,960,000	20,793,000	26,454,000	12,698,000	7,133,000	1,616,000	71,654,000
1940	2,313,000	12,507,000	9,204,000	10,156,000	7,712,000	3,328,000	45,220,000
1941	398,000	29,376,000	54,106,000	33,905,000	10,312,000	2,294,000	130,391,000
1942	----------	12,462,000	19,047,000	10,259,000	4,661,000	2,019,000	48,448,000
1943	836,000	16,556,000	10,327,000	11,872,000	5,087,000	429,000	45,107,000
1944	----------	14,302,000	25,823,000	10,943,000	1,105,000	584,000	52,757,000
1945	556,000	9,330,000	7,980,000	756,000	688,000	72,000	19,382,000
1946	560,000	1,377,000	3,175,000	4,279,000	937,000	----------	----------
1947	7,181,000	63,330,000	49,255,000	15,826,000	----------	----------	----------
1948	1,061,000	21,818,000	19,228,000	----------	----------	----------	----------
1949	136,000	3,854,000	----------	----------	----------	----------	----------
1950	6,000	----------	----------	----------	----------	----------	----------

TABLE 16

Number of Fish Landed by Year Class at Each Age Group From 0 Through V

TABLE 17

Pounds of Fish Landed by Year Class at Each Age Group 0 Through V

Year class	AGE GROUP						Totals
	0	I	II	III	IV	V	
1934						6,851,000	
1935					12,141,000	1,885,000	
1936				31,946,000	14,592,000	1,414,000	
1937			19,306,000	22,163,000	7,015,000	1,178,000	
1938		11,578,000	49,762,000	27,249,000	6,651,000	1,499,000	96,739,000*
1939	961,000	11,609,000	21,747,000	12,898,000	9,058,000	2,334,000	58,607,000
1940	853,000	7,564,000	7,809,000	10,743,000	10,139,000	4,809,000	41,917,000
1941	116,000	15,085,000	40,066,000	36,527,000	13,595,000	3,236,000	108,625,000
1942		7,912,000	16,208,000	11,453,000	6,225,000	2,863,000	44,661,000
1943	274,000	9,991,000	9,221,000	12,786,000	6,718,000	638,000	39,628,000
1944		7,296,000	22,530,000	13,035,000	1,484,000	852,000	45,197,000
1945	158,000	5,627,000	7,601,000	867,000	899,000	100,000	15,252,000
1946	129,000	1,015,000	2,365,000	4,070,000	1,078,000		
1947	1,477,000	29,643,000	32,320,000	14,692,000			
1948	248,000	8,612,000	13,591,000				
1949	47,000	2,155,000					
1950	1,000						

* No information available on the 0 age group of the 1938 year class.

TABLE 17

Pounds of Fish Landed by Year Class at Each Age Group 0 Through V

For those year classes on which complete information is available, the 1945's with slightly over 19,000,000 were the poorest contributors. The 1946 year class will undoubtedly fall far short of even the 19,000,000 low of the 1945 group.

Table 17 shows pounds of fish contributed by each year class for each age group from zero through five. This table reveals that the 1941 year class was unquestionably the better contributor when compared to 1938, its closest rival. It seems extremely unlikely that the zero year old fish of the 1938 year class could have amounted to the 13,000,000 pounds which would be necessary to even equal the 1941 group. Particularly is this true in view of the fact that small fish were not accepted by the canners in any quantity during those years. From this table it may be inferred that the 1945 year class was the poorest; however, again the 1946 year class will be even poorer. On the other hand, the 1947 year class which has to date contributed tremendous numbers has been extremely poor from a poundage point of view.

Figure 16, A through L, shows the percentage of catch in pounds and numbers of fish at each age for each season from 1939–40 through 1950–51. These percentages best illustrate the effect of the fishery on dominant year classes from one season to the next. The contributions of the 1938, 1941, and 1947 year classes can be compared at any particular age. In making these comparisons it is necessary to remember that these figures show only the percentage contribution for the particular season being studied. The 51.5 percent contributed by the 1938 year class as two-year-olds during the 1940–41 season amounted to over 70,000,000 fish (Table 15), and yet the 62.8 percent and the 63.9 percent contributed by the 1941 and 1947 year classes as two-year-olds (1943–44 and 1949–50 seasons) amounted to only 54 and 49 million fish, respectively.

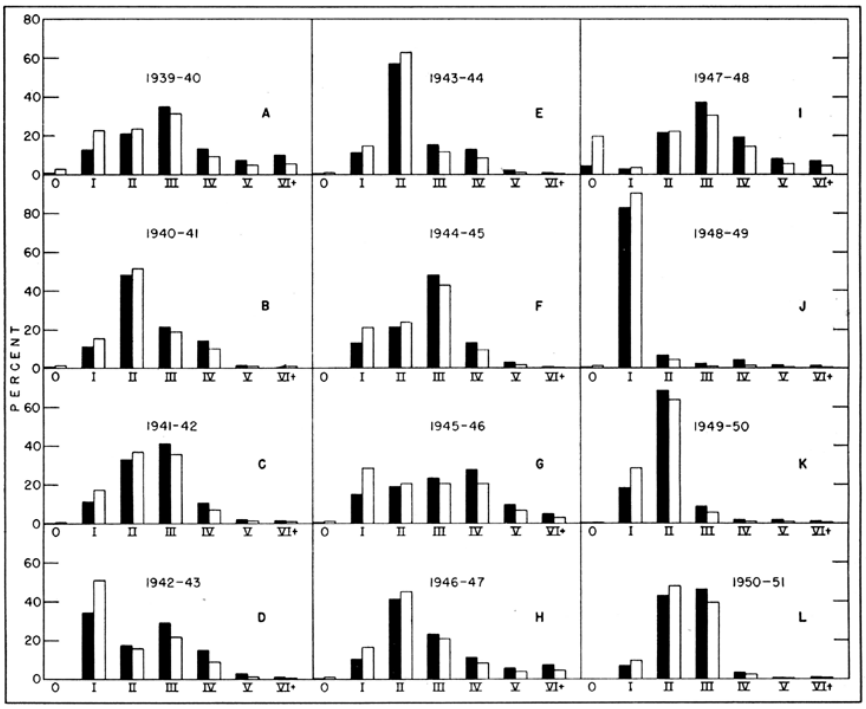

FIGURE 16. The percentage of catch by season in pounds (shaded bars) and numbers (unshaded bars) of fish at each age

FIGURE 16. The percentage of catch by season in pounds (shaded bars) and numbers (unshaded bars) of fish at each age

Greatest percentage contribution of any single age group during a season was the 90.3 percent furnished by the 1947 year class as one year old fish during the 1948–49 season. This 90.3 percent was only slightly more than 63,000,000 fish (Table 15).

From Figure 17 it may be seen that landings of mackerel age zero were quite comparable for all seasons except 1947–48. Most of the 19.8 percent taken during 1947–48 was landed during a few days late in the season when no other fish were available. The sardine fishery was at one of the lowest ebbs in its history and fishermen and canners were willing to accept anything they could obtain. For more than a week purse seiners docked with loads of 10 or 15 tons of these eight- and nine-inch mackerel. All thoughts of conservation or the future needs were completely forgotten as greed and "don't give a damn" attitudes took over on the parts of both fishermen and the canning industry. The situation became so critical that the California Fish and Game Commission had to place emergency minimum size limitations effective immediately on the Pacific mackerel. This move was supported by those canners and fishermen who realized the damage that was being done. Had not such regulations been enacted it is entirely possible that a promising year class would have been utterly depleted before it was 12 months of age, two full years before attainment of sexual maturity.

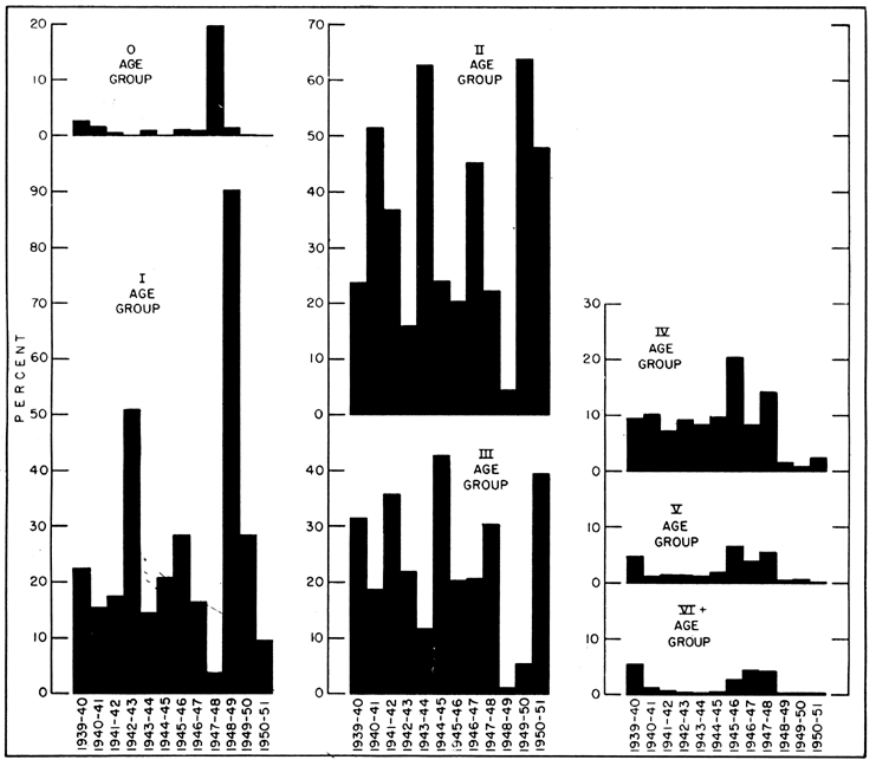

FIGURE 17. The percentage of the catch furnished by each age group 0 through VI + for seasons 1939-40 through 1950-51

FIGURE 17. The percentage of the catch furnished by each age group 0 through VI + for seasons 1939–40 through 1950–51

Figure 17 shows that on the average the one-year-olds made up about 20 percent of any single season's catch. Three exceptions to this are the 1942–43 and 1948–49 landings, which are both well above the average, and the 1947–48 season one-year-olds, which fall far short of the 20 percent mark. Greatest irregularity from one year to the next of any age group is with the two-year-olds. Mackerel four years of age and older are practically nonexistent in the fishery at present and have been scarce since the 1947–48 season.

Fluctuations in abundance of Pacific mackerel are due in most part to the success or failure of incoming year classes. This is well illustrated by Figure 12, which shows that all but 13 percent of the average season's catch based on 12 years of landings is contributed by fish three years of age or less. All but 15 percent of the average seasonal landings have been furnished by three age groups: two's, one's and three's in order of importance. Nearly 65 percent of the fish caught during the 12 seasons' studies were less than three years of age. These fish would not have spawned or would have spawned only once.

6. FUTURE OUTLOOK FOR PACIFIC MACKEREL

The future of the Pacific mackerel in California is not a bright one. The fishery during the past 10 years has been fading rapidly toward ultimate destruction. The reserve spawning stock over four years of age has dwindled until in 1950–51 less than 3 percent of the Pacific mackerel caught were four years of age and older (Figure 16L). More and more is a successful fishing season dependent upon incoming year classes and good, dominant year classes are few and far between. Even when such year classes do enter the fishery as in 1947–48, they alone cannot support the entire fishery and their numbers are often seriously reduced before they have had a chance to spawn.

In former years there was a successful spring and early summer fishery, but that disappeared completely nearly a decade ago and has never returned. The scoop fleet which for years fished successfully during January, February and March now seldom fishes through December. With the failure of the sardine fishery and the resultant increased fishing pressure of the purse seine fleet on the Pacific mackerel there was no substantial increase in landings. More canneries and boats, larger boats, radio-telephone, fathometers and gear improvements have all been contributing factors to the dwindling mackerel supply. How long the Pacific mackerel can survive this onslaught is anyone's conjecture. Both jack mackerel (Trachurus symmetricus) and sardines (Sardinops caerulea) are fished in the same waters as Pacific mackerel and all three species are used for canning. As a result, the purse seiners are actually fishing for one of three species, but will substitute either of the other two if acceptable to the canners. Prosecution of the fishery will continue so long as there is a profit to be obtained. Thus, even when fishing for mackerel alone is no longer profitable, these fish will still be taken by vessels in search of the other species. Closed seasons, over-all yearly bag limits, and minimum size restrictions would no doubt help relieve this situation, but it is doubtful if even these will bring the mackerel back to their former abundance.

This decline in abundance of Pacific mackerel has been largely masked by the increase in landings of jack mackerel, so that many in the industry are unaware of what has happened to the Pacific mackerel fishery. Since jack mackerel cannot be successfully chummed and scooped, the scoop fishermen have felt the effect of this decline to a much greater extent than the purse seiners and realize that a once lucrative fishery no longer exists.

7. SUMMARY

Otoliths are a valid means of determining age of Pacific mackerel and more than 98 percent are readable.

Ninety-one percent of the otoliths have an opaque or summer margin during July and 82 percent have a translucent or winter margin during January. For the purpose of this report all otoliths are deemed to have a completed winter ring on May 1 and a completed summer ring on October 1.

Pacific mackerel sampling is carried on routinely at different canneries in Los Angeles and Orange counties throughout each season. Otoliths are saved from each sample. The number of otoliths taken per individual sample is dependent upon the size range of the fish in that sample.

From age determination of Pacific mackerel it is obvious that the fishery is dependent almost entirely upon fish less than four years of age in most years and less than three years of age in some years.

The Pacific mackerel does not reach one pound in weight or spawn more than once before most of the fish in any one year class have been caught. The oldest fish for which a definite age could be determined had completed eleven winters and was in its twelfth year when caught.

During the 1948–49 season the fishery was dependent almost entirely upon the dominant 1947 year class which contributed over 90 percent of the total catch. These fish were in age group I (12–23 months) at that time and weighed less than a half pound each.

The greatest contribution by any single year class (age 0 through V) was made by that of 1941 which produced 130,000,000 fish weighing 109,000,000 pounds. The smallest contribution was by the 1945 year class with over 15,000,000 pounds from 19,000,000 fish.

The future outlook for the Pacific mackerel fishery is not good. All signs indicate that the peak of abundance has been passed and the population is now at a low ebb and being reduced to still lower levels.

APPENDIX A
MONTH AND SEASON SUMMARIES
MONTH SUMMARIES
General Information
At the end of each calendar month the daily sample sheets (Figure 2) are summed by cross addition at each length. For the striker and scoop boat samples the number of fish at each length is determined for each of three fishing localities, Santa Monica Bay, Santa Catalina Island and all of the inshore area south of Santa Monica Bay. The information on these three summary sheets is then cross added to give a final month summary for all scoop and striker boats. Net boat samples are summed without regard to fishing locality. A month summary total is made by combining all scoop and striker boat summaries with the net boat summary. This all-gear, all-locality summary shows all of the fish sampled during a particular month at each length. This frequency is then converted into a percentage for each length.

The statistical section of the Bureau of Marine Fisheries tabulates mackerel landings by gear, area and month from information contained on the fish receipts. From these statistical records are obtained the pounds of fish landed from any particular area and for any particular type of fishing gear. This poundage divided by the average weight of fish sampled from that area, gear and month gives the calculated number of fish which were taken from that particular area.

Example
Assume a hypothetical month summary for Santa Monica Bay scoop and striker boats for March, 1951. From this locality 500 fish which weighed 250 pounds were sampled during March. The average weight would thus be 0.5 pounds. From the statistical report it is found that 100,000 pounds were landed from scoop and striker boats fishing Santa Monica Bay during this month. At one-half pound apiece this would mean 200,000 fish were caught.

Daily sample sheets show that of these 500 fish sampled five measured 110 quarter centimeters. These five fish therefore would be 1 percent of the total sampled. The 200,000 fish taken during the month multiplied by this 1 percent gives a calculated catch of 2,000 fish 110 quarter centimeters long. Calculations are similarly made for all lengths represented in the month summary.

SEASON SUMMARY
The season summary is compiled from cross-addition of all of the all-gear, all-locality month summaries for a given mackerel fishing season (May 1 through April 30). Thus the season summary is a frequency array which depicts the season's mackerel catch as the calculated number of fish at each length.

APPENDIX B
WEIGHTING PROCEDURE
HYPOTHETICAL EXAMPLE

In Appendix A it was assumed that 500 scoop and striker caught mackerel were sampled during March, 1951, from 200,000 such fish caught in Santa Monica Bay. For the same month we will now assume that scoop and striker boats caught 100,000 fish at Santa Catalina Island and 200,000 fish in the inshore area south of Santa Monica Bay. In addition 500,000 mackerel were taken by net boats during March. This would total 1,000,000 mackerel for all gear, all localities during this month. of this number only 1,000 were sampled and otoliths were removed from 100 of the 1,000. All of these otoliths were aged, therefore for every fish from which otoliths were removed there would have been 10,000 fish (1,000,000/100 = 10,000) from which no otoliths were taken. This number of fish from which no age determinations were made becomes the weighting factor. For convenience in calculating, the last two figures are dropped from the factor. For March the factor is 10,000; dropping the last two figures gives 100 and this 100 is then multiplied by the number of fish at each age and length as determined by the 100 otolith readings. A weighting factor is similarly worked out for each month of each season and the calculations made.

In Table 18 weighting factors actually used for the 1950–51 season are computed. It may be seen from this table that during May and August, 1950, landings were quite heavy and the otoliths read were relatively few, thus the weighting factor was quite high. Conversely the weighting factor for February was relatively small due to light landings and fairly numerous age determinations. No otoliths were taken during either June, 1950, or January, 1951, and while landings of these months were used in calculating number of fish, these computations were worked from the season curve as determined from fish sampled during all the other months.

Table 19 shows how these weighting factors were used on four-year-old fish for the 1950–51 season. Two of the July otoliths were aged as four, one each from fish 128 and 136 quarter centimeters in length, and each of these was weighted as 916, the factor for July. The five fish 136 quarter centimeters long, from which otoliths aged four were read in September, were weighted as 1,960 or five times the September factor 392. Similar calculations were worked for each month for all otoliths read and the weighted figures cross added at each length for each age group.

TABLE 18

Weighting Factors for 1950-51 Season Calculated by Dividing Number of Fish Aged Into Number of Fish Landed for Each Month of the Season

Month	Mackerel landed / Otoliths read	= factor	Factor used
May	1383987 / 6	= 230664.	2307
July	3847569 / 42	= 91608.	916
August	4178459 / 26	= 160709.	1607
September	14891322 / 380	= 39187.	392
October	4093789 / 247	= 16574.	166
November	4157722 / 212	= 19611.	196
December	2085816 / 52	= 40111.	401
February	146574 / 22	= 6662.	67
March	282240 / 7	= 40320.	403
April	1262688 / 36	= 35074.	351

TABLE 18

Weighting Factors for 1950–51 Season Calculated by Dividing Number of Fish Aged Into Number of Fish Landed for Each Month of the Season

TABLE 19

Actual Weighting for Four-Year-Old Fish for the 1950-51 Season. Each Month Is Weighted Separately at Each Length and Then All Months Cross-added at Each Length

Length ½ cms	July		August		September		October		November		December		Sums	
	Otoliths read	wtd.	Otoliths read	wtd.	Otoliths read	wtd.	Otoliths read	wtd.	Otoliths read	wtd.	Otoliths read	wtd.	Otoliths read	weighted
125														
6														
7														
8	1	916											1	916
9														
130														
1							2	332					2	332
2							1	166					1	166
3														
4					1	392							1	392
135							2	332	1	196			3	528
6	1	916			5	1,960	3	498	2	392			11	3,766
7					4	1,568	2	332	1	196	1	401	8	2,497
8					1	392	1	166					2	558
9					3	1,176	1	166					4	1,342
140							4	664					4	664
1			1	1,607	5	1,960	3	498	1	196			10	4,261
2					2	784	2	332	1	196			5	1,312
3					1	392	2	332	1	196			4	920
4			1	1,607	3	1,960	1	166			2	802	9	4,535
145							1	166					1	166
6														
7							3	498					3	498
8							1	166					1	166
9									1	196			1	196
150														
1														
2														
3							1	166					1	166
4														
155														

TABLE 19

Actual Weighting for Four-Year-Old Fish for the 1950–51 Season. Each Month Is Weighted Separately at Each Length and Then All Months Cross-added at Each Length

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